622.09
Un32mo
no.2800-2854
1927-28
cop.2
inc.

BINDING POSTS CAN BE CUT

If too tightly bound to photocopy, please take to circulation desk so personnel can remove plastic posts.

Digitized by the Internet Archive
in 2018 with funding from
University of Illinois Urbana-Champaign Alternates

https://archive.org/details/reportofinvestig2800unit

622.09
Un32mo
cop.2

Serial No. 2800
March, 1927.

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

CONSUMPTION OF EXPLOSIVES IN FEBRUARY, 1927.

By W. W. Adams[1]

Explosives manufactured in the United States and sold in February 1927 for domestic consumption are estimated at 530,700 kegs of 25 pounds each of black blasting powder, 5,412,000 pounds of permissible explosives, and 22,154,000 pounds of high explosives other than permissibles. These estimates are based on actual sales of 520,078 kegs of powder, 5,403,594 pounds of permissibles, and 20,815,703 pounds of other high explosives reported by manufacturers to the U. S. Bureau of Mines, Department of Commerce. As compared with sales in February last year the figures indicate increases in all three classes of explosives as follows: 6 per cent for black blasting powder, 26 per cent for permissibles, and 7 per cent for high explosives other than permissibles.

PERMISSIBLE EXPLOSIVES: The amount of permissibles sold in January and February was 11,673,000 pounds, including 11,655,931 pounds actually reported by manufacturers and an estimate to cover sales by companies from whom no reports were received. As compared with the same months last year, the figures show an increase of 33 per cent, due mainly to the fact that the anthracite mines were working in January and February 1927, while they were idle for most of the corresponding months last year. Ninety-six per cent of the permissibles sold thus far in 1927 were for use in coal-mining operations, the anthracite mines using 25 per cent and the bituminous mines 71 per cent. The consumption of permissibles at bituminous coal mines since January 1st has averaged 76 pounds for each thousand tons of coal mined; this amount represented 25 per cent of the 306 pounds of all kinds of explosives consumed per thousand tons of bituminous coal produced. At anthracite mines 234 pounds (30 per cent) were used for each thousand tons of anthracite coal produced.

OTHER HIGH EXPLOSIVES: Sales of high explosives other than permissibles amounted to 43,661,000 pounds during the first two months of 1927. This amount includes 41,024,253 pounds sold by reporting companies and an estimate for several companies that do not furnish a report of sales. The amount of explosives sold thus far in 1927 shows an increase of 7 per cent over sales during the same two months in 1926. Continuous work during these two months in 1927 at anthracite mines, which use large quantities of high explosives, was no doubt the cause of this increase, as the mines were idle all of January and most of

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

February last year. Of the total amount of this class of explosives sold thus far during the present year, 14 per cent was for coal mining; 35 per cent for metal mining, 23 per cent for quarrying and nonmetallic mineral mining, 15 per cent for railway and other construction work, and 13 per cent for miscellaneous purposes. In the mining of bituminous coal since January first, 306 pounds of all kinds of explosives have been used for each thousand tons of coal produced, and of this amount 14 pounds (4 per cent) were high explosives other than permissibles. The anthracite mines used explosives at the rate of 775 pounds per thousand tons and of this amount 361 pounds (47 per cent) were "high" explosives.

BLACK BLASTING POWDER: The quantity of black blasting powder sold during the first two months of 1927 was 1,147,700 kegs, including 1,124,805 kegs sold by reporting companies and an estimate of sales by nonreporting companies. These figures represent an increase of 8 per cent in volume of sales as compared with the corresponding months last year. Of the total amount sold, 90 per cent was for use in coal-mining operations, while the remaining 10 per cent was used for metal mining, quarrying, construction work and all other purposes. Of 306 pounds of all types of explosives used at bituminous coal mines since the first of the year for each thousand tons of coal produced, 216 pounds (71 per cent) were black blasting powder. At the anthracite mines where 775 pounds of all classes of explosives were used per thousand tons, 180 pounds (23 per cent) were black blasting powder.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in February were more than 358,000 kegs, showed that the mills were operated to 54 per cent of their capacity in February as compared with 54 per cent in January, 48 per cent in December, and 43 per cent in February last year. The amount of explosives remaining on hand at the close of February represented 58 per cent of one month's manufacturing capacity of the mills reporting, as compared with 43 per cent at the close of February a year ago.

	February, 1926	February, 1927	Jan.-Feb.,1927
Capacity (kegs)........	953,583	796,083	1,592,166
Manufactured...........	407,616	432,028	860,232
Per cent of capacity...	43	54	54
Shipments..............	382,992	373,156	814,550
Per cent of capacity...	40	47	51
Sales..................	353,124	358,348	808,029
Per cent of capacity...	38	45	51
Stocks, end of month...	409,508	458,884	458,884
Per cent of capacity...	43	58	29

The following percentage figures show the extent of capacity to which mills manufacturing black powder were operated in 1924, 1925, 1926, in each month of 1926 and the months of January and February, 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month of the current year.

	Manufactured	Shipments	Sales	Stocks
Year 1924..............	41	41	41	3.8
Year 1925..............	38	39	38	3.2
Year 1926..............	40	40	39	3.6
1926				
January.................	42	42	42	40
February................	43	40	38	43
March...................	40	40	41	43
April...................	38	36	36	44
May.....................	31	28	28	47
June....................	32	34	32	44
July....................	35	34	35	45
August..................	39	38	36	46
September...............	43	45	44	43
October.................	45	49	49	40
November................	52	53	52	38
December................	48	42	42	43
1927				
January.................	54	55	56	50
February................	54	47	45	58

Reports from 22 mills that sold more than 22 million pounds of permissibles and other high explosives in February showed that the mills were operated to 63 per cent of their capacity in February as compared with 59 per cent in January, 63 per cent in December, and 61 per cent in February last year. The amount of explosives remaining on hand at the close of February represented 20 per cent of one month's manufacturing capacity of the mills reporting, as compared with 17 per cent at the close of February a year ago.

	February, 1926	February, 1927	Jan.-Feb.1927
Capacity (pounds).........	39,153,332	38,945,000	77,890,000
Manufactured.............	23,696,133	24,582,149	47,723,722
Per cent of capacity......	61	63	61
Shipments................	22,795,098	24,249,112	46,939,936
Per cent of capacity......	58	62	60
Sales....................	20,381,656	22,143,794	44,517,706
Per cent of capacity......	52	57	57
Stocks, end of month......	6,539,281	7,672,438	7,672,438
Per cent of capacity......	17	20	10

The percentage of full-time capacity to which mills manufacturing permissibles and other high explosives were operated in 1924, 1925, 1926, during each month of 1926, and in the months of January and February 1927 is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining on hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924............	62	62	59	1.4
Year 1925............	62	62	59	1.5
Year 1926............	68	68	64	1.4
1926				
January...............	51	51	50	17
February.............	61	58	52	17
March.................	68	69	63	18
April.................	65	65	64	18
May...................	69	73	69	15
June..................	76	76	71	15
July..................	67	69	68	13
August................	74	72	73	15
September............	77	77	70	16
October..............	76	74	70	19
November.............	69	73	65	15
December.............	63	61	59	17
1927				
January...............	59	58	57	19
February.............	63	62	57	20

PYROTOL: During the first two months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 2,007,950 pounds of pyrotol, of which 1,190,900 pounds represented shipments in February. During the corresponding two months last year the shipments amounted to 3,034,700 pounds of which 1,568,200 pounds represented February shipments. Most of these explosives were intended for land clearing and for building roads. Table D shows the amount of pyrotol shipped to each State in February 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal mining operations in each State in January and February is shown in Table C. Table D shows the quantity of pyrotol distributed in February to the various States, and the purpose for which used. -- Reports of Investigations, Department of Commerce, Bureau of Mines.

TABLE A - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during February, 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	11,115	748,150	449,750
Alaska	-	248,800	2,000
Arizona	240	110,800	-
Arkansas	4,746	116,825	11,850
California	4,625	1,214,060	-
Colorado	4,236	475,220	94,800
Connecticut	35 Rtd	21,800	-
Delaware	-	6,250	-
Florida	800	944,750	-
Georgia	4	216,125	-
Idaho	2	305,825	-
Illinois	111,655	531,925	389,550
Indiana	73,185	272,100	15,925
Iowa	19,010	71,125	500
Kansas	31,670	582,775	54,675
Kentucky	52,210	303,050	279,300
Louisiana	-	264,585	24,250
Maine	27	28,525	-
Maryland & D.C.	1,074	195,025	16,850
Massachusetts	28	60,850	-
Michigan	57	1,524,425	-
Minnesota	1,205	849,968	-
Mississippi	41	145,900	-
Missouri	4,985	730,700	9,655
Montana	3,599	551,225	-
Nebraska	402	17,450	-
Nevada	2,240	254,300	-
New Hampshire	29	2,000	-
New Jersey	2	168,825	-
New Mexico	2,814	103,250	1,500
New York	878	1,001,100	3,850
N. Carolina	1,523	434,675	2,000
N. Dakota	2,831	26,100	2,000
Ohio	19,901	677,550	24,700
Oklahoma	9,210	804,110	37,384
Oregon	1,344	206,600	-
Pennsylvania	75,327	3,266,526	2,565,480
Rhode Island	11	2,250	-
S. Carolina	165	64,825	-
S. Dakota	102	100,835	1,000
Tennessee	9,334	440,075	14,400
Texas	11,211	463,865	50
Utah	1,500	666,025	132,200
Vermont	41	29,150	-
Virginia	5,811	294,100	139,800
Washington	1,786	569,884	42,000
West Virginia	47,633	361,350	1,046,125
Wisconsin	405	247,675	-
Wyoming	1,099	92,400	42,000
TOTAL FEBRUARY 1927	520,078	20,815,703	5,403,594

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first two months of 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	20,721	1,471,875	902,950
Alaska	–	358,850	4,000
Arizona	650	190,100	–
Arkansas	9,703	239,389	17,300
California	11,312	2,390,755	–
Colorado	11,091	863,720	220,300
Connecticut	16 Rtd	52,750	–
Delaware	–	6,250	–
Florida	5,910	2,128,400	–
Georgia	1,981	368,275	–
Idaho	492	703,055	8,850
Illinois	240,763	982,975	852,350
Indiana	136,887	425,400	130,925
Iowa	45,513	206,225	1,000
Kansas	61,816	1,329,285	110,240
Kentucky	110,303	428,075	553,550
Louisiana	250	492,005	24,300
Maine	101	50,750	–
Maryland & D.C.	4,838	340,275	28,700
Massachusetts	128	82,700	–
Michigan	91	2,942,075	–
Minnesota	2,138	1,577,868	–
Mississippi	881	219,300	–
Missouri	17,216	1,364,400	30,180
Montana	12,730	1,144,555	8,000
Nebraska	858	34,050	–
Nevada	4,100	530,350	200
New Hampshire	31	12,700	–
New Jersey	10	351,650	–
New Mexico	3,787	121,900	47,500
New York	1,571	1,667,224	3,850
N. Carolina	3,522	697,125	2,000
N. Dakota	5,656	38,075	4,000
Ohio	56,393	1,282,625	46,750
Oklahoma	22,407	1,961,630	50,491
Oregon	3,916	448,700	–
Pennsylvania	167,310	6,898,301	5,436,770
Rhode Island	37	5,050	–
S. Carolina	912	131,275	–
S. Dakota	167	195,575	1,300
Tennessee	17,941	664,900	81,000
Texas	14,266	982,880	50
Utah	4,650	1,418,975	237,200
Vermont	531	53,800	–
Virginia	12,168	638,775	296,000
Washington	4,283	1,113,036	114,225
West Virginia	100,946	700,500	2,307,800
Wisconsin	879	510,050	50
Wyoming	2,965	205,800	134,100
TOTAL 1st 2 MOS. 1927	1,124,805	41,024,253	11,655,931

FEBRUARY, 1927.

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs	Pounds	Pounds
Quantity used for:			
Coal mining....................	468,883	2,688,748	5,166,894
Metal mining....................	3,230	7,413,079	6,775
Quarrying and nonmetallic mineral mining................	17,481	4,852,398	39,400
Railway and other construction work.........................	17,735	3,270,476	23,175
All other purposes.............	12,749	2,591,002	167,350
TOTAL FEBRUARY 1927.............	520,078	20,815,703	5,403,594

JANUARY TO FEBRUARY, 1927, INCLUSIVE.

	Black blasting powder	High explosives other than permissible	Permissible explosives
Quantity used for:			
Coal mining....................	1,015,413	5,704,199	11,190,306
Metal mining....................	7,209	14,450,089	14,350
Quarrying and nonmetallic mineral mining................	40,513	9,619,723	104,800
Railway and other construction work.........................	32,397	6,023,398	36,675
All other purposes.............	29,273	5,226,844	309,800
TOTAL 1st 2 MOS. 1927...........	1,124,805	41,024,253	11,655,931

TABLE C – Quantity of explosives sold for use in COAL MINES in February 1927 by manufacturers rendering monthly reports.

(Including cumulative figures for the first two months of 1927)

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama........	8,164	16,216	55,100	104,600	441,750	890,600
Arkansas.......	4,676	9,613	3,700	11,700	1,300	1,300
Colorado.......	3,345	8,412	15,950	43,675	84,000	209,000
Illinois.......	111,408	240,039	73,275	126,775	349,600	795,275
Indiana........	72,194	135,589	64,600	111,150	15,425	124,425
Iowa...........	17,894	43,978	6,400	45,850	500	1,000
Kansas.........	30,366	60,094	83,450	160,276	54,525	109,990
Kentucky.......	50,046	104,261	75,950	140,600	253,550	505,150
Maryland.......	800	4,116	500	4,500	13,350	15,950
Michigan.......	36	70	2,400	6,700	–	–
Missouri.......	4,484	14,993	10,400	30,600	9,655	22,030
Montana........	2,630	8,650	–	–	–	3,000
New Mexico.....	–	15	250	2,350	1,000	47,000
North Dakota...	2,784	5,501	23,225	28,350	2,000	4,000
Ohio...........	17,969	51,423	35,225	70,725	5,050	14,450
Oklahoma.......	7,319	19,748	2,150	28,100	37,384	46,641
Penna.(Bitum.).	28,039	71,645	87,175	257,550	1,139,405	2,451,370
Tennessee......	7,818	16,382	5,100	39,150	14,200	80,300
Texas..........	4,610	5,550	150	2,150	–	–
Utah...........	–	–	–	15,400	129,700	234,700
Virginia.......	3,958	9,216	20,250	49,950	139,600	291,800
Washington.....	901	2,326	3,000	9,150	35,400	67,900
West Virginia..	45,892	98,182	74,000	167,750	993,175	2,249,550
Wyoming........	1,064	2,010	2,700	14,100	42,000	114,100
Other States...	10	30	1,000	20,800	4,000	14,150
Total (Bitum.).	426,407	928,059	645,950	1,491,951	3,766,569	8,293,731
Penna. (Anth.).	42,476	87,354	2,042,798	4,212,248	1,400,325	2,896,575
Grand total as reported....	468,883	1,015,413	2,688,748	5,704,199	5,166,894	11,190,306

Est. total inc. non-reporting companies	Anth.	89,100	4,484,000	2,901,000
	Bitum.	947,000	1,589,000	8,305,000
Total reported plus estimate		1,036,100	6,073,000	11,206,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period February 1, 1927 to February 28, 1927.

State	State Highway Department Roads	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
Alabama............	2,000	16,000	-	-	18,000
Georgia............	-	16,000	-	-	16,000
Idaho..............	-	86,850	-	-	86,850
Iowa...............	-	125,000	-	-	125,000
Kansas.............	6,000	-	-	-	6,000
Maryland...........	-	650	-	-	650
Minnesota..........	50,000	56,000	-	-	106,000
Missouri...........	-	32,000	-	-	32,000
Montana............	5,000	27,600	-	-	32,600
Nebraska...........	20,000	-	-	-	20,000
New Mexico.........	3,500	-	-	-	3,500
N. Carolina........	15,500	149,800	-	-	165,300
Oregon.............	36,000	86,900	-	-	122,900
S. Carolina........	750	23,600	-	-	24,350
Virginia...........	-	16,000	-	-	16,000
Washington.........	32,000	299,750	-	-	331,750
West Virginia......	-	16,000	-	-	16,000
Wisconsin..........	-	68,000	-	-	68,000
Total February.....	170,750	1,020,150	-	-	1,190,900
Total January......	93,000	704,050	-	20,000	817,050
Grand Total........	263,750	1,724,200	-	20,000	2,007,950

Serial No. 2801
April, 1927

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

TESTS WITH ROCK DUST FOR EXTINGUISHING FIRE

By H. C. Howarth[1] and H. P. Greenwald[2].

PURPOSE OF TESTS.

The preliminary tests referred to in this report were made at the Bureau's Experimental Mine under the general supervision of G. S. Rice, chief mining engineer, to determine whether rock dust may be used to extinguish or control mine fires.

DESCRIPTION OF THE DUST USED

The dust used for application by hand was made from draw slate taken from the Experimental Mine. This draw slate was crushed in a hammer-type crusher fitted with 1/16 inch by 2-inch slotted screens. A sizing test of the dust showed 96.5 per cent through 20 mesh, 69.4 per cent through 48 mesh, 46.2 per cent through 100 mesh, and 33.5 per cent through 200 mesh.

The dust contained about 10 per cent combustible matter, 2 per cent moisture, and 88 per cent ash.

The dust used in the rock-dusting machine was made from shale taken from a bed about 60 feet below the Pittsburgh coal bed at the Experimental Mine. This dust contained about 2 per cent moisture and 1 per cent combustible matter. A sizing test of the dust gave 99.9 per cent through 20 mesh, 95.8 per cent through 48 mesh, 79.6 per cent through 100 mesh, and 62.7 per cent through 200 mesh.

TEST METHODS

In all of the tests reported the dust was applied either by means of a modern rock-dust distributor having a movable discharge pipe or by shoveling it on the fire by hand.

In order that the workmen might not be exposed to danger and to prevent damage to the Experimental Mine, the tests were conducted at the mouth of the aircourse where the entry is lined with concrete and at a point where the smoke

---

[1] Coal-mine superintendent, Experimental Mine, Bruceton, Pa.
[2] Associate physicist, Pittsburgh Experiment Station, Bureau of Mines.

from the fire might be carried directly to the fan. With this arrangement it was possible to control the volume of air passing over the fire. When gas was used the tests were made outside of the mine; this was also done when lubricating oil was used.

DETAILS OF TESTS AND RESULTS

Test 1. - In this test a rock-dust distributor was used. The fire was in the aircourse, 50 feet from the mouth. Forty pounds of kindling wood (pieces averaging about 2 inches square and about 2 feet long) was piled in the shape of a cone and in such a manner that it burned rapidly and made an intense fire. The machine was placed on the intake side of the fire with the end of the discharge-pipe 25 feet from the burning wood. About 26,000 cubic feet of air at a velocity of 450 feet a minute was passing over the fire. When the fire was burning at the maximum possible to obtain with this amount of wood, a stream of dust, estimated at 125 pounds a minute, was directed toward the fire for a period of three minutes. This was the heaviest stream obtainable from the machine. During this 3-minute period a thin coating of dust was deposited on the unburned portions of wood, but it had no effect on the fire.

Test 2. - Twenty pounds of kindling wood was added to the fire and the machine was moved so that the end of the discharge pipe was 15 feet from the fire. The ventilating current was the same as in test 1. The stream of dust was directed toward the fire for a period of 7 minutes. During this time the fire was enveloped in a cloud of dust so dense that observers could not see any signs of fire from a distance of 15 feet. When the machine was stopped the upper surfaces of many of the sticks of wood was coated with a 1/16-inch layer of dust. Some of the sticks were charred beneath the dust, indicating that they had been burning; but the general appearance of the fire at the end of this time showed that the dust had made little or no impression on it.

Test 3. - Conditions of this test were the same as tests 1 and 2. A new fire using 30 pounds of wood was started. The machine was placed so that the end of the discharge pipe was 20 feet from the fire and the stream of dust was directed toward the fire for a period of 5 minutes. The intensity of the fire was slightly reduced and there was a coating of dust about 1/8-inch thick on the upper surfaces of the top pieces of wood. About 50 pounds of dust (5 shovelfuls) was carefully placed on the fire, completely smothering the flame. Two hours later the mass had cooled to the extent that it was possible to hold the burned wood in the hand.

Test 4. - In this test a mine car containing about 500 pounds of coal, spread in a layer about 10 inches deep in the bottom of the car, was placed in the aircourse 50 feet from the mouth. The ventilation was the same as in the previous tests. The fire was started at the outby end of the car so that the ventilating current carried smoke and flame over the coal in the car. When about half of the coal was burning briskly the stream of rock dust was directed toward the fire from a distance of 30 feet for 25 minutes. At the end of this period the fire was gaining headway and there was a 1/8-inch layer of dust on the unburned coal in the car. Most of the dust appeared to have been carried beyond the fire. The

ventilating current was cut down to about 500 cubic feet a minute and the rock-dust distributor again operated for 30 minutes. During this period the intensity of the fire was noticeably reduced. This may have been partly due to reducing the ventilating current. There was a 1-inch coating of dust over the front of the fire and about the same thickness over the unburned part of the coal toward the back end of the car, but there was no dust over the central part of the fire. A total of about 3000 pounds of dust was used in the two runs made in this test.

The conclusions drawn from this test are (1) that a high velocity air current carries the dust beyond the fire; (2) convection currents set up by the fire prevents dust from settling on the hottest part of the fire; and (3) operation of the machine for several hours with no air moving as in a dead end, may result in the deposition of a blanket of dust that would have a retarding effect on fire.

Test 5. - Two timber sets made of old oak props were erected in the aircourse 45 feet from the mouth. The sets were about 5 feet apart and lagged with old props on the top and both sides. The clear space inside of the sets was about 5 feet wide by 5 feet high. A fire was started near the bottom on both sides at the outby end with kerosene-soaked waste. About 15,000 cubic feet of air at a velocity of 250 feet a minute was passing. The fire burned somewhat slowly for 10 minutes and the air was increased to about 26,000 cubic feet at a velocity of 460 feet. Twenty minutes after the fire was started all the side lagging and some of the top lagging on one side and about half the lagging on the other side was burning. The machine was operated with the end of the discharge pipe 25 feet from the fire and dust was discharged at the rate of about 80 pounds a minute, but the fire was not much affected in 5 minutes. The volume of air was reduced to 15,000 cubic feet a minute and the operation of the machine continued for 5 minutes. The fire was checked somewhat but the fire area was not much reduced. During the next 5-minute period the fire was checked a little more but blazed up again as soon as the machine was stopped. The ventilation was then reduced to about 500 cubic feet a minute and the machine operated 10 minutes. The main part of the fire was not much affected, but around the edges it was being quenched. A part of the dust used to this time fell to the floor short of the fire area. The machine was moved to a point 15 feet from the fire and after it had been in operation 3 or 4 minutes the entire set, including the lagging, collapsed. Fire was burning briskly in the collapsed pile of props and was quenched with water. About 2500 pounds of rock dust was used in the entire test but it had little or no effect on the fire.

Test 6. - In this test 1000 pounds of run-of-mine coal from the Experimental Mine was placed on a bed of kindling wood in the aircourse 45 feet from the mouth. The area covered was 5 feet square and the depth about 8 inches. Small quantities of pit-car oil was added from time to time after the fire was started to hasten burning. One hour after starting, about 80 per cent of the pile was burning briskly and two men began throwing rock dust on it, from a distance of 15 feet, with No. 2 canal shovels. When 30 shovelfuls (300 pounds) had been thrown on the fire it was completely under control. It was left in this condition for 2-1/2 hours during which time it continued to smolder. Water was then thrown on the fire a bucketful at a time until 15 gallons had been applied. The first water thrown on the fire washed some of the shale dust down and the fire had a tendency to burn up again.

On examination it was found that all of the coal was well charred; some near the front of the bed where the fire was started was coked.

Test 7. - In this test a wood and coal fire 24 inches in diameter at the base and 18 inches high in the center was made on the ground outside of the mine. After the fire had been burning for about 45 minues a bucket (made from a 25-pound powder-keg) 2/3 full of pit-car oil was placed on top of the burning heap. When the oil began to boil over, the bucket was upset and made a very intense fire. Rock dust was then thrown on the fire by means of No. 2 shovels. The first shovelful was directed at the oil bucket and it quenched the flame therein. About 400 pounds of dust was required to cover the fire completely and put it under control.

Test 8. - This is a group of three tests in which an attempt was made to determine whether rock dust would be effective in extinguishing gas flames. In the first two of these, flaming natural gas flowing from the open end of a 1-1/2-inch pipe was extinguished by throwing rock dust at it by shovelfuls. In one of these tests the gas was flowing at the rate of 15 cubic feet a minute and in the other at the rate of 20 cubic feet a minute. In either case the flame was easily extinguished by a single shovelful of dust directed at the base of the flame.

In the third test a flat sheet of iron 6 by 5 feet was blocked up 5 inches from the ground with bricks placed at each corner. Three sides were packed with earth, leaving the fourth side open and about the same height as the kerf in the average undercut in a mine room or entry. The 1-1/2-inch gas pipe referred to above was placed opposite the open side. With the burning gas issuing from the large opening along the side of this flat sheet of iron it was very difficult for one man using a No. 2 shovel to extinguish the flame by throwing rock dust at it, but two men throwing shovelfuls simultaneously extinguished the flame at every attempt. Gas in this case was flowing at the rate of 20 cubic feet a minute. With the gas burning as in the last case, rock dust was carefully placed, a shovelful at a time, so as to close the opening along the fourth side of the sheet iron. This crowded the burning gas to one corner and as the opening was being closed, the gas was forced through the earth filling around the other three sides. This caused the flame to spread over the earth filling, a small tongue of flame issuing at each little crevice in the dirt. In appearance, this fire was very much like gas burning over a freshly shot cut of coal and required the efforts of two ment throwing rock dust simultaneously to extinguish it. After extinguishing the flame by this method three or four times, the gas was again ignited and rock dust was carefully placed over the loose earth to fill the crevices and concentrate the gas at one point. With the flame concentrated at one point it was an easy matter to extinguish it with a shovelful of dust.

CONCLUSIONS

1. The results of the tests indicate that rock dust may be used effectively for controlling fire when it may be approached and the dust applied direct. This applied to fires on the floor or in any position where it can be covered with dust. The quantity of dust required will depend upon the area of the fire.

2. The tests indicate that a blanket of dust 2 inches thick will be sufficient to shut off the air supply completely and smother the flame.

3. One of the chief advantages that rock dust has over water is that there is no steam to add to the discomfort of the fire-fighters, and it does not evaporate and permit the fire to burn up again.

4. In the case of burning gas, the flame may be gradually concentrated and finally extinguished when the gas is coming from the bottom or any place that can be covered with dust.

5. When the gas flowing from drill-holes at the working faces of coal mines has been ignited, the flame may easily be extinguished with a shovelful of rock dust, if the dust is so directed that it will momentarily interrupt the flow of gas.

6. In the experiments with the rock-dusting machine, the intensity of the fire was reduced in one or two cases but the results were not as encouraging as had been expected. The best results with the machine were obtained when the ventilation was reduced to almost zero. Satisfactory results may be obtained with the machine in the case of a fire in a dead end, as at the face of an entry, if the machine is placed at the last cut-through and the stream of dust directed toward the fire. This experiment could not easily be made without exposing the men engaged to considerable danger; also there was the possibility of starting a fire that would get beyond control resulting in considerable damage to the mine. - Reports of Investigations, Bureau of Mines, Department of Commerce.

622.8
Un3m
cop.2

Serial No. 2803
April, 1927.

622.09
Un32mo
COP 2

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

COAL-MINE FATALITIES IN MARCH, 1927

MAY 1 9 1927
UNIVERSITY OF ILLINOIS

By W. W. Adams[1]

Accidents at all coal mines in the United States during the month of March, 1927, caused the death of 178 men, according to reports furnished by State mine inspectors to the Bureau of Mines, Department of Commerce. The production of coal during the month was 66,279,000 tons, of which 60,181,000 tons was bituminous and 6,098,000 tons was anthracite. Of the 178 fatalities reported, 139 were in bituminous mines and 39 in anthracite mines. Fatality rates based on these figures were 2.31 and 6.40, respectively, while the industry as a whole showed a rate of 2.69 per million tons of coal produced.

An explosion on March 30 at Ledford, Illinois, caused the death of 8 men. This is the first major disaster --- that is, a disaster causing the death of 5 or more men --- that has occurred during the present year. During the first three months in 1926 there were 7 major disasters, killing 189 men. The fatality rates based exclusively on these major accidents were 0.042 per million tons for 1927 and 1.201 for 1926.

Records for the first three months of 1927 show 561 fatalities at coal mines as compared with 693 for the corresponding period of 1926. The production of coal in these periods was 188,478,000 tons and 157,422,000 tons, respectively, indicating a fatality rate for 1927 of 2.98 and for 1926 of 4.40 per million tons. The fatality rate for the three-month period of 1927 was 2.58 for bituminous mines alone, based on a production of 169,967,000 tons and 438 fatalities, and 6.64 for anthracite mines, based on a production of 18,511,000 tons of coal and 123 fatalities. In 1926 the rate for this period for bituminous mines, based on 146,376,000 tons and 641 fatalities, was 4.38; while anthracite showed a rate of 4.71 based on 11,046,000 tons and 52 fatalities.

Comparing the figures for all mines for the three-month period, January to March, with those for the same months last year, a reduction during the present year is noted in the per-million-ton fatality rate for falls of roof and coal, haulage, and gas or dust explosions; while explosives and electricity each showed a slight increase. The comparative rates were as follows:

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

	Year 1926	Jan.-Mch. 1926	Jan.-Mch. 1927
All causes	3.789	4.402	2.976
Falls of roof and coal	1.829	1.829	1.560
Haulage	.650	.680	.578
Gas or dust explosions	.636	1.302	.191
Explosives	.143	.107	.127
Electricity	.143	.114	.127

Table 1 gives comparative figures showing the number of deaths per million tons from each of the principal causes of accidents for the year 1926, and for the first three months of 1926 and 1927, respectively. Table 2 shows fatal accidents in March, 1927, classified by causes and States. Table 3 shows fatalities in January, February, and March, by months and States.

Table 4 is a comparative table showing the percentage of fatalities and the number of deaths per million tons of coal produced for each of the principal causes of accidents at both bituminous and anthracite mines, separately, for the ten-year period 1917-1926, and for the years 1925 and 1926; it also shows the average March rate over a ten-year period. A similar comparison may also be made with February, 1927, with March 1926, and with March 1927. Table 5 shows the tons of coal produced per man employed for the United States and for Nova Scotia for the years 1908 to 1926. The table shows that the production is higher for the United States in every year. - Reports of Investigations, Department of Commerce, Bureau of Mines.

TABLE 1.- NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES.

	Year 1926	Jan.-Mch. 1926	Jan.-Mch. 1927
Falls of Roof & Coal..................	1.829	1.829	1.560
At face............................	1.386	1.340	1.146
In room............................	.238	.273	.223
On entry...........................	.193	.216	.191
On slope...........................	.012	-----	-----
Haulage...............................	.650	.680	.578
Switching and spragging............	.020	.032	.005
Coupling...........................	.008	.006	.021
Falling from trips.................	.030	.025	.037
Run over...........................	.241	.210	.260
Caught between car and rib.........	.136	.153	.138
Caught between car and roof........	.027	.019	.016
Runaway cars.......................	.057	.025	.043
Miscellaneous......................	.131	.210	.058
Gas or Dust Explosions................	.636	1.302	.191
Open light.........................	.191	.083	.079
Defective safety lamp..............	.005	-----	-----
Electric arc.......................	.081	.006	.043
Shot...............................	.077	.254	.021
Powder explosion...................	.005	.006	-----
Miscellaneous......................	.277	.953	.048
Explosives............................	.143	.107	.127
Transportation.....................	-----	-----	-----
Charging...........................	.006	.019	-----
Suffocation........................	.008	.013	-----
Drilling into old holes............	.001	-----	-----
Striking in loose rock.............	-----	-----	-----
Thawing............................	-----	-----	-----
Caps & detonators..................	.001	.006	.005
Unguarded shots....................	.006	.006	.005
Returned too soon..................	.013	.006	.016
Premature shot.....................	.048	.013	.016
Sparks from lamp, etc..............	.005	.013	.016
Delayed shots......................	.015	.006	.016
Shot breaking through rib..........	.011	.006	.032
Miscellaneous......................	.029	.019	.021
Electricity...........................	.143	.114	.127
Direct contact with trolley wire.....	.050	.019	.064
Tools striking trolley wire..........	.003	.013	-----
Contact with mining machine..........	.013	.006	.005
Contact with machine feed wire.......	.009	.019	.032
Contact with haulage motor...........	.003	-----	-----
Miscellaneous........................	.065	.057	.026

TABLE 2.- COAL-MINE FATALITIES DURING MARCH, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ga. & N. C.	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																														
Falls of roof	2	-	-	3	-	12	5	-	2	3	-	-	-	-	2	-	5	1	21	-	-	-	1	2	-	20	1	80	15	95
Falls of side	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	3	-	6	9	15
Haulage	1	-	-	2	-	1	2	-	-	2	-	-	-	-	-	-	1	-	5	-	-	-	-	-	-	11	-	25	3	28
Gas or dust explosions	-	-	-	-	-	8	-	-	-	1	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	13	3	16
Explosives	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	2	2	4
Suffocated by mine gases	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3
Electricity	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	-	-	1	-	8	-	8
Animals	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Mining machines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1
Mine fires	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	3
TOTAL	6	-	-	7	-	22	7	1	2	6	-	-	-	-	2	-	6	2	32	-	1	-	2	3	-	37	1	137	37	174
SHAFT																														
Persons falling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Objects falling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cages, skips	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SURFACE																														
Mine cars	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electricity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1
Machinery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Boiler explosions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Railway cars	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
TOTAL	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	2	4
GRAND TOTAL, March, 1927	6	0	0	7	0	23	7	1	2	6	0	0	0	0	2	0	6	2	32	0	1	0	2	3	0	38	1	139	39	178
GRAND TOTAL, March, 1926	5	0	1	6	1	11	6	0	1	14	0	0	0	1	3	0	9	2	24	0	1	0	0	3	2	53	3	146	40	186

TABLE 3.- COAL-MINE FATALITIES DURING 1927, BY MONTHS AND STATES

MONTH	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January.............	6	-	2	8	19	3	1	-	23	-	1	1	1	2	-	7	2	35	-	3	-	1	2	1	42	4	164	43	207
February...........	7	-	2	5	11	6	1	2	10	-	-	-	1	1	2	9	2	29	-	-	-	5	5	2	35	-	135	41	176
March..............	6	-	-	7	23	7	1	2	6	-	-	-	-	2	-	6	2	32	-	1	-	2	3	-	38	1	139	39	178
Total, 3 months...	19	0	4	20	53	16	3	4	39	0	1	1	2	5	2	22	6	96	0	4	0	8	10	3	115	5	438	123	561

TABLE 4.- AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED.

Cause of accident	Per cent of total, 1917-1926	Death rates per million short tons						
		Average for 10 years 1917-1926	Year 1925	Year 1926	Average for Mch. 10 years 1917-1926	1927 Feb.	1927 Mch.	1926 Mch.
Bituminous Mines								
1. Falls of roof and coal	48.97	1.758	1.750	1.717	1.609	1.361	1.429	1.474
2. Underground haulage	18.18	.653	.586	.655	.654	.643	.416	.693
3. Explosions of gas or coal dust	13.75	.494	.581	.645	.808	.038	.216	.520
4. Explosives	3.29	.118	.094	.078	.115	.113	.033	.087
5. Electricity	4.01	.144	.154	.161	.099	.113	.133	.065
6. Mining machines	1.33	.048	.069	.045	.037	.038	.017	.022
7. Other causes underground	2.93	.105	.087	.067	.092	.038	.033	.065
8. All causes underground	92.46	3.320	3.321	3.368	3.414	2.344	2.277	2.926
9. All shaft accidents	1.73	.062	.058	.047	.044	.038	------	.043
10. All accidents on surface	5.81	.209	.148	.147	.202	.170	.033	.195
11. All accidents	100.00	3.591	3.527	3.562	3.660	2.552	2.310	3.164
Anthracite Mines								
1. Falls of roof and coal	42.71	2.496	2.750	2.588	2.477	2.563	3.936	2.730
2. Underground haulage	12.75	.745	.906	.612	.826	1.025	.492	.683
3. Explosions of gas	8.22	.480	.696	.576	.345	.684	.492	------
4. Explosives	12.37	.723	.857	.588	.628	.513	.328	.341
5. Electricity	1.00	.059	.065	.024	.024	------	------	------
6. Other causes underground	8.18	.478	.323	.459	.419	1.367	.820	.114
7. All causes underground	85.23	4.981	5.597	4.847	4.719	6.152	6.068	3.868
8. All shaft accidents	2.30	.134	.065	.094	.185	.170	------	.228
9. All accidents on surface	12.47	.729	.809	.388	.641	.684	.328	.455
10. All accidents	100.00	5.844	6.471	5.329	5.545	7.006	6.396	4.551

Table 5.- Tons of coal produced per man employed.
(Nova Scotia and United States compared).

Year	Nova Scotia[1]	United States
	Production per man. Tons of 2,000 lbs.	Production per man. Tons of 2,000 lbs.
1908.......	545	603
1909.......	545	691
1910.......	558	692
1911.......	553	682
1912.......	572	740
1913.......	590	762
1914.......	536	673
1915.......	569	724
1916.......	665	818
1917.......	628	860
1918.......	569	890
1919.......	523	713
1920.......	563	839
1921.......	491	615
1922.......	424	565
1923.......	540	763
1924.......	369	733
1925.......	319	777
1926.......	554	(2)

1/ Report of the Mines, 1926. Department of Public Works & Mines, Halifax, N. S., page 331.

2/ Not available.

Serial No. 2805
May, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

KNOWN ACCUMULATION OF GAS IGNITED BY UNAPPROVED ROCK-DUSTING MACHINE.

By L. D. Tracy[1] and C. W. Owings.[2]

Introduction

Many bituminous coal-mining companies have inaugurated extensive safety programs, but the failure to have approved or permissible equipment or safe practice in only one part of a mine has resulted in disaster. The necessity of using only equipment bearing the U. S. Bureau of Mines approval plate is emphasized by the fact that many accidents are the direct result of carelessness on the part of trusted employees using non-permissible equipment. A concrete example is found in the case of an explosion on October 26, 1926, in a mine in the Pittsburgh district, Pennsylvania.

Story of the Explosion

At about 10 o'clock on the night of the explosion an examination was made in No. 2 butt left and parallel off No. 14 north, and was found to be clear of dangerous accumulations of gas. (See figure). Several hours later a crew of two men brought a self-propelling rock-dusting machine within 50 feet of the face of No. 2 butt parallel before they examined for gas. The machine operator found an accumulation of explosive gas about 18 inches from the roof. He began to wave his arms thoroughly mixing the gas and air. Undoubtedly a highly explosive mixture was created, and as the men attempted to run the machine back to fresh air an explosion occurred.

The helper dropped to the floor and was burned about the face and wrists. The machine operator ran down the entry and was more severely burned about the face, neck, and arms. He later developed pneumonia and died. Both men reached the door in the chute between No. 14 and No. 15 north. A pumper, who had felt the rush of air, found the men and helped them to walk outside.

Evidence

The evidence following was noted by a Bureau of Mines engineer: No. 14 north is the haulage-road in a set of 6 face entries. The three right entries are intakes and the three left entries are returns. The air, after passing across the faces of these entries, returns through No. 2 butt parallel and No.

---

[1] - Coal-mining engineer.

[2] - Associate coal-mining engineer.

2 butt, then out No. 16 north face parallel. In the chute between 14 and 15 north, leading to No. 2 butt, is a door which opens outby. The door is well constructed and has two iron strap-hinges extending across its entire width. After the explosion this door was found to be open and damaged. The machine helper does not remember noticing that the door was damaged nor that it was left open. In order to determine the cause of the damage, the door was set up in the entry and the locomotive operating in this section was run up to it, but the dents in the door did not coincide with the frame of the locomotive. The rock-dusting machine was then brought up to the door and the dents coincided with the frame of the machine. Therefore, it was proved that upon entering the entry the rock-dusting machine had damaged the door, which would not close, thereby short-circuiting the air and allowing gas to accumulate at the face of No. 2 butt parallel.

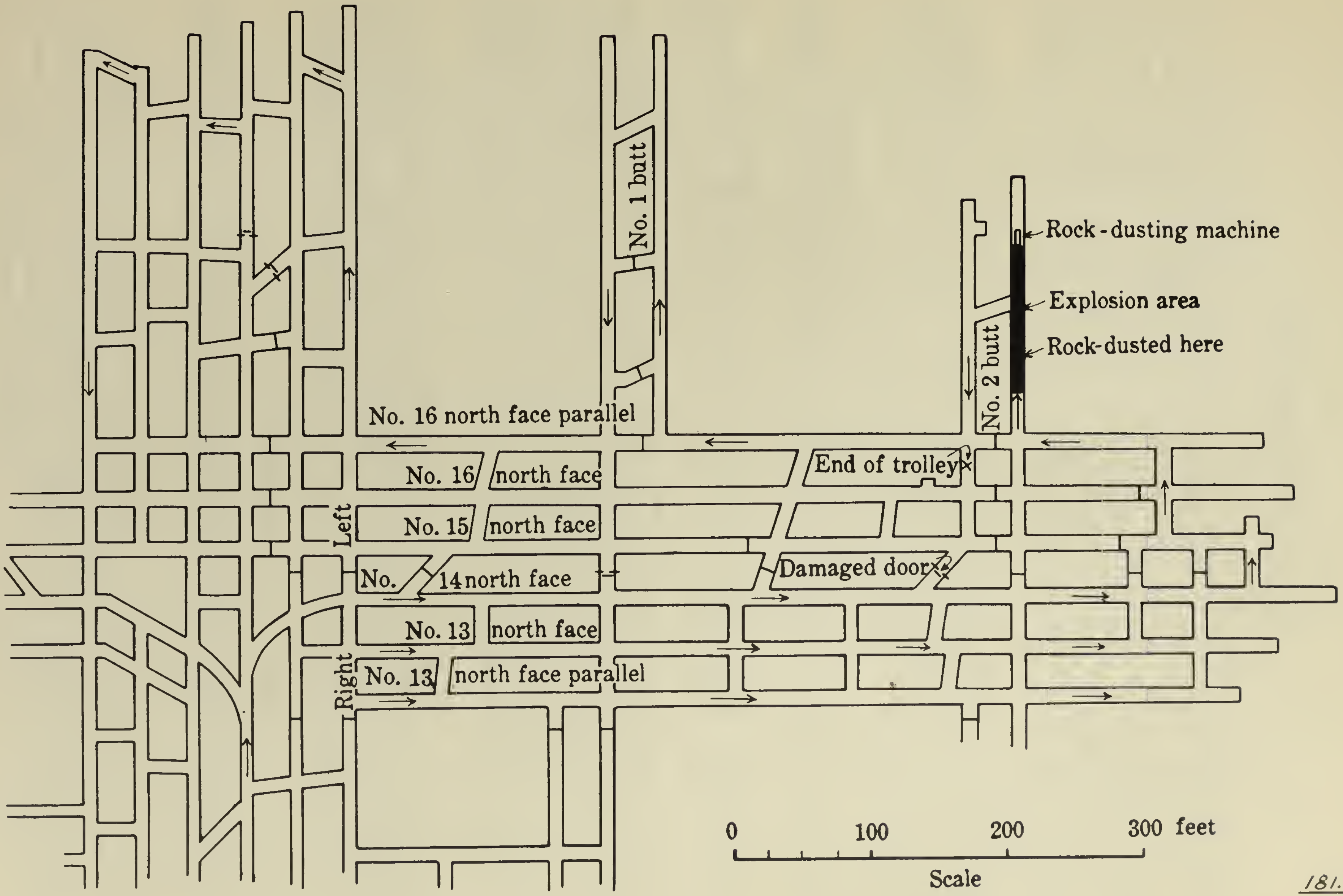
Further investigation revealed that an appreciable period had elapsed after the door had been damaged and before the machine-runner went to the face of No. 2 butt and its parallel, to test for gas. He found gas but thought that his safety lamp was defective and went outside where he procured another lamp. Upon returning to No. 2 butt he took the rock-dusting machine into the entries without making a second test for gas.

After ventilation had been restored, an anemometer reading taken in the last crosscut on No. 2 butt showed that 15,000 cubic feet of air a minute was passing at this point. The general practice at the mine is to maintain a line brattice within one cut of the face, especially where gas is likely to be found. At the time of the explosion, line brattices were within 10 feet of the face of No. 2 butt and its parallel.

An inspection of the explosion area did not reveal any signs of force and there was little evidence of intense heat except in the entry in which the ignition occurred. This area is shown on the plan. Coke globules on the inby side of the posts showed that a flame had come down this portion of the entry. There were slight evidences of heat in No. 2 butt, although not as pronounced as in the aircourse.

Although the floor is not wet it is damp, and it would appear that there was not enough force to raise a cloud of coal dust of sufficient proportions to propagate an explosion. There was no evidence of coked dust; the coke globules already mentioned were the dust coked in place.

The entries had been rock-dusted to within 125 feet of the face, but as another break-through was nearly cut through it was intended to rock-dust the parallel entry before the track was removed, as is the practice in this mine, as soon as a break-through is completed. The damp condition of the coal dust and the application of rock dust so near the face undoubtedly prevented a general explosion.



181.06
1

Part of mine showing place of ignition.

Safe Practices at this Mine.

At this mine safe practices are numerous and safety rules are vigorously enforced. Safety starts at the outside and extends to the working face. Before entering the mine the miners are provided with an approved electric cap-lamp and the officials with an approved magnetically-locked flame safety lamp. Each man is checked in and out of the mine. The manway is an enclosed compartment in the supply slope. At the slope-mouth there is a mechanically-operated figure continually emerging from and re-entering a box. This figure draws attention to safety practices and the necessity of leaving matches and smoking materials outside. The men are searched for matches before entering the mine.

All equipment except the rock-dusting machine taken to the working face is permissible. All mining machines are of the approved type. Storage-battery locomotives and mules gather coal at the face. No trolley wire is taken nearer than 200 feet from the face. Permissible explosives are used with clay tamping and the shots are fired by shotfirers using permissible shotfiring batteries.

A strong air current is carried to the face of all entries. Permanent stoppings are of concrete blocks and temporary brattices are of wood. Line brattices are used beyond the last crosscut to conduct the air to the face.

Fire protection is afforded by placing suitable fire extinguishers at central points and by keeping sacks of limestone dust in all sections of the mine.

Rock-dusting was started in October, 1924, and a systematic plan has been followed since then. All rooms and entries are rock-dusted to the last break-through. The entry in which the explosion originated was rock-dusted to the last break-through. The entries driven prior to 1925, and which are inaccessible to the rock-dusting machine, are protected by strategically placed rock-dust barriers. This was the first mine to receive full credit for rock-dusting by the Coal Mine Section of the Pennsylvania Compensation Rating and Inspection Bureau.

A safety inspector is engaged at this mine. A week before the disaster he had spent three nights with the rock-dusting crew, instructing them as to safe practices. They were told to enter a place and test for gas before taking in the rock-dusting machine. This safety rule was adopted because, although the motors on the machine were enclosed, they were not a permissible type.

Conclusion

This explosion was caused by a non-permissible rock-dusting machine igniting a body of gas, which had accumulated when the machine damaged a door to such an extent that it would not close and thus short-circuited the air.

This accident could have been prevented if the employees had observed the safety rules of the company. Even if the rules were disobeyed, the accident could have been prevented by using only permissible equipment. There is reason to believe that the rock dusting done, together with naturally damp condition of some nearby workings, prevented a general explosion.-- Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un 32 mo
cop. 2

STATE GEOLOGICAL SURVEY

Serial No. 2807.
May, 1927.

REPORTS OF INVESTIGATIONS
DEPARTMENT OF COMMERCE - - BUREAU OF MINES

PROPERTIES OF TYPICAL CRUDE OILS FROM THE PRODUCING FIELDS OF VENEZUELA.

THE LIBRARY OF THE
JUL 28 1958
UNIVERSITY OF ILLINOIS

By A. J. Kraemer[1]

Introduction

In 1925 the Bureau of Mines published as Technical Paper 346 a discussion of typical crude oils of the Western Hemisphere[2]. That paper was one of a series of surveys of typical crude oils[3], and was the first of these to deal with properties of crude oils from countries other than the United States. The paper contains comments, tabulated data, and individual analyses of crudes typical of the producing districts of Canada, Mexico, Trinidad, Venezuela, Argentina, Colombia, and Peru; for comparison, it also has analyses of typical crudes from the chief producing districts of the United States.

---

[1] Associate petroleum chemist, Bureau of Mines, Washington, D. C.

[2] Kraemer, A. J., and Calkin, L. P., Properties of typical crude Oils from the Producing Fields of the Western Hemisphere, Technical Paper 346.

[3] Dean, E. W., Properties of typical crude oils from the Eastern producing fields of the United States: Reports of Investigations, Bureau of Mines, Serial 2202, January, 1921.

Dean, E. W., Cooke, M. B., and Bauer, A. D. Properties of typical crude oils from the producing fields of the Rocky Mountain District: Reports of Investigations, Bureau of Mines, Serial 2235, March, 1921.

Dean, E. W., Bauer, A. D., and Lerch, W. B. Viscosities and pour tests of typical crude oils from the Eastern and Rocky Mountain producing fields of the United States: Reports of Investigations, Bureau of Mines, Serial 2290, October, 1921.

Dean, E. W., Cooke, M. B., and Bopp, C. R. Properties of typical crude oils from the producing fields of northern Texas, northern Louisiana and Arkansas: Reports of Investigations, Bureau of Mines, Serial 2293, November, 1921.

Dean, E. W., Cooke, M. B., and Bauer, A. D. Properties of typical crude oils from the producing fields of Kansas: Reports of Investigations, Bureau of Mines, Serial 2322, February, 1922.

Dean, E. W., Bauer, A. D., Cooke, M. B., and Bopp, C. R. Properties of typical crude oils from the producing fields of Oklahoma: Reports of Investigations, Bureau of Mines, Serial 2364, June, 1922.

Smith, N. A. C., Cooke, M. B., and Bauer, A. D. Properties of typical crude oils from the producing fields of southern Louisiana and southern Texas: Reports of Investigations, Bureau of Mines, Serial 2416, November, 1922.

Kraemer, A. J., and Smith, H. M. Properties of typical crude oils from the producing fields of California: Reports of Investigations, Bureau of Mines, Serial 2595, April, 1924.

Kraemer, A. J., and Smith, H. M. Properties of California crude oils; II, Additional analyses: Reports of Investigations, Bureau of Mines, Serial 2608, May, 1924.

The Bureau of Mines undertook a study of foreign crude oils for two reasons: First, foreign fields are potential sources of supply for the United States; in fact, considerable quantities of some foreign crudes have already been imported. Second, these oils are very similar in physical and chemical properties to oils found in the United States, and a study of these resemblances has scientific value.

After the publication of Technical Paper 346, the attention of the Bureau was called to the fact that the two analyses of crude oil from Venezuela which appeared in that paper were not completely representative of the production of that country. Samples of other types of oil were procured through the cooperation of Mr. R. Ogarrio, manager of the Texas Petroleum Co., Houston, Texas, and officials of the following companies operating in Venezuela: British Controlled Oilfields, Ltd., Venezuelan Oil Concessions, Ltd., Creole Syndicate, and Venezuelan Gulf Oil Co., Samples were collected and dispatched by Mr. D. E. Park, representative in Maracaibo, Venezuela, of the Texas Petroleum Co. The value of the interest and cooperation of these agencies in obtaining the samples is gratefully acknowledged.

Methods of Analysis

The methods employed in testing and analyzing the samples are described in detail in Bureau of Mines Bulletin 207[4]. For a discussion of the interpretation of crude oil analyses as made by the Bureau of Mines, see Serial No. 2806[5].

Discussion of Results

The properties of a group of crude oils can be adequately discussed only by considering a great number of details, for no two crudes are exactly alike. However, a method of interpretation, along the lines indicated has been undertaken. Also, wherever analogies appear which indicate similarity to a typical crude oil of the United States, this similarity is pointed out.

If errors or omissions are noted by any reader, the Bureau of Mines hopes that he will call them to its attention that they may be corrected before the final bulletin goes to press.

Table 2 summarizes the results of these analyses by presenting some of the figures indicating the physical and chemical properties of the crudes. Table 3 presents figures for the gravities of the fractions distilling at atmospheric pressure between 250° and 275°C. and also for the pour points of the fractions distilling between 275° and 300°C. at 40 mm. absolute pressure. These figures indicate in a general way the "base" of a crude oil. (see Serial No. 2806[5a]).

---

[4] Dean, E. W., and others, The Analytical Distillation of Petroleum and its Products, Bureau of Mines Bulletin 207, 1922, 82 pp. Obtainable from the Government Printing Office, Washington, D. C. at 15 cents a copy.

[5] Smith, N. A. C. The Interpretation of Crude Oil Analyses, Reports of Investigations, Bureau of Mines, Serial 2806, May, 1927.

[5a] Smith, N. A. C., work cited.

Gravities are reported in A. P. I. degrees. This is the scale formerly known in the American petroleum industry as "Baume" based on the modulus 141.5 as distinguished from the true Baume scale based on the modulus 140.0 [6].

Analyses of two samples from the Lake Maracaibo basin, which were printed in Technical Paper 346 are included in this report. The crudes are much alike, being fairly heavy, black oils, rather high in sulphur (average 2.58 per cent), rather low in "gasoline and naphtha" (average 11.9 per cent), and containing considerable proportions of vacuum distillates, which do not show wax content. They show no kerosene distillates by the Bureau of Mines analysis and interpretation. The carbon residue of residuum is high, as might be expected from the large content of sulphur. The samples are similar to many of the crudes, especially the heavier high-sulphur oils, of Kern County, California[7]. These Kern County crudes do not contain as much sulphur as the Venezuela samples and the carbon residue of residuum is correspondingly less. In other respects the Kern County and the Venezuela crudes are much alike.

Samples No. 26275, from the Ambrosio field of the State of Zulia is quite similar to sample No. 1163 from the second zone of the Santa Maria field of California. The gravities of corresponding cuts in the distillation of the two oils are nearly equal, and the viscosities and cloud tests of corresponding cuts in the vacuum distillation are similar. The sulphur content is less in the Ambrosio sample than in the Santa Maria crude.

The "gasoline and naphtha" content of the Santa Maria oil is higher than for the Ambrosio crude. Neither crude has a kerosene fraction according to the Bureau of Mines method of analysis and interpretation. The Venezuela oil shows more gas oil than the California sample, and the content of lubricating distillates is approximately equal.

The Ambrosio crude shows a general resemblance to some of the wax-bearing crudes of the Southern California fields, but the sulphur content is higher, and the individual fractions are heavier in gravity in the Ambrosio crude than in the Southern California oils.

Sample No. 26276 from La Rosa field of the State of Zulia, is similar to the high-sulphur oils among the wax-bearing crudes of the southern California fields. In this connection see samples No. 23515, No. 1141 and No. 1146. The sulphur content is about equal for all of these crudes. The cuts in the air distillation are generally lighter in gravity in La Rosa crude than corresponding cuts in the southern California oils. In the vacuum distillation, the situation is reversed; vacuum fractions of La Rosa crude are heavier in gravity than corresponding fractions in the southern California samples. The viscosities and cloud tests of corresponding cuts are nearly equal for all of these crudes.

---

[6] A concise statement of the reasons for the general adoption of the A. P. I. gravity scale has been prepared by the American Petroleum Institute, 15 West 44th Street, New York, New York.

[7] Kraemer, A. J. and Smith, H. M. Serial 2595. See note 3.

The "gasoline and naphtha" content of La Rosa sample is less than in the California crudes. The kerosene content is about equal for all of them. The California samples contain slightly more gas oil than La Rosa crude. The lubricating distillates total about 20 per cent for all of these crudes, and the variations in the proportion between nonviscous, medium and viscous distillates is small.

Sample No. 26273 from La Concepcion field of the State of Zulia is very similar to Mid-Continent crudes of the United States which have a comparatively large content of sulphur. See for example, sample No. 646 from Oklahoma, No. 23434 from Texas, and No. 716 from Arkansas. The sulphur content of all of these crudes is rather high and ranges from 0.72 per cent for sample No. 646, from Oklahoma, to 1.01 per cent for sample No. 23434 from Texas. The gravities of corresponding cuts throughout the distillation range are approximately equal for all of these crudes and the viscosities and cloud tests of vacuum fractions are also similar. The "gasoline and naphtha" content of sample No. 716 is larger than for the three other crudes, and the fraction is also lighter in gravity. The kerosene content of La Concepcion crude is larger than that of either of the Mid-Continent crudes.

Sample No. 26274 from El Mene field of the State of Falcon, is unique insofar as the analyses in the files of the Bureau of Mines are concerned. Except for the relatively small sulphur content, and the presence of wax in the vacuum fractions, the crude is similar to typical naphthenic California crudes. No wax-bearing California crudes in the files of the Bureau of Mines have as heavy gravities in corresponding fractions as El Mene crude. The crude is placed in the "hybrid" class by the Bureau of Mines method of interpretation.

El Mene crude appears to be a high-grade oil, with its "gasoline and naphtha" content of 47.4 per cent, and low sulphur content and cloud point of vacuum fractions, indicating the applicability of residues as stock for cracking processes.

Production Data

The crude oil production of Venezuela for the year 1926, was 37,238,532 barrels, according to O'Shaughnessy's South American Oil Reports for January, 1927.

The following table showing daily average crude oil production by fields, for December 1926, is taken from a similar table in the above mentioned report.

Table I

Daily Average Crude Oil Production for December, 1926
Barrels of 42 U. S. Gallons. Partly estimated.

Field	Barrels	Field	Barrels
La Rosa	72,664	Benitez	3,513
Mene Grande	18,600	La Paz	3,406
Lagunillas	16,252	Concepcion	2,277
Ambrosio	5,519	Guanoco	1,935
El Mene	7,714	Total	131,880

Summary

This report contains analyses of representative samples of crude petroleum from the producing fields of Venezuela. The report is a revision of the discussion contained in Bureau of Mines Technical Paper 346 and presents additional analyses of Venezuela crude oils.

On the basis of the analyses and the sampling data, the characteristics of the crudes have been discussed, and any analogies to typical crude oils of the United States have been pointed out.

Data are presented showing the production for the year 1926 and the average daily production by fields for the month of December, 1926.

Table 2

Data showing sources of samples and some of the figures indicating physical chemical Properties

Sample Number	State	Field	Properties of Crude				Gasoline Fraction		Viscosity at 100°F. of Vacuum Fractions			% Carbon Residue of Residuum
			°API	o/o S.	Viscosity at 100°F.	Pour Test °F.	o/o	°API	225-250	250-275	275-300	
VENEZUELA												
23539	-	Mene Grande	16.0	2.65	1370	(a)	9.2	48.3	79	165	379	19.1
998	-	-	17.9	2.51	790	(a)	14.6	53.2	100	224	(b)	22.4
26275	Zulia	Ambrosio	21.3	2.02	307	(a)	13.2	55.4	69	116	250	17.8
26276	do	La Rosa	25.2	1.69	133	(a)	18.9	57.4	66	105	200	14.9
26273	do	La Concepcion	33.4	0.88	52	(a)	21.0	54.2	61	95	159	9.0
26274	Falcon	El Mene	35.2	0.38	34	(a)	47.4	55.7	80	154	(b)	15.2
UNITED STATES												
1163	Calif.	Santa Maria	23.0	2.63	252	(a)	21.8	52.7	78	154	321	15.5
23515	do	Huntington Beach	26.3	1.29	99	30	22.3	54.0	70	118	248	13.1
1141	do	Richfield	25.9	1.60	106	15	25.2	56.7	73	136	267	17.2
1146	do	Ventura Co.	24.5	1.79	105	10	23.7	55.4	67	126	258	13.7
646	Okla.	Healdton	31.1	0.72	64	(a)	22.3	56.4	71	111	193	9.0
23434	Texas	-	33.0	1.01	66	20	22.8	55.4	56	82	153	8.2
716	Arkansas	El Dorado	34.6	0.83	46	(a)	30.7	61.0	60	81	132	10.3

(a) below 5°F. (b) more than 400 seconds Saybolt Universal

Table 3

Showing Figures Indicative of the "Base" of the Oils

Sample Number	State	Field	Fraction Distilling at atmospheric pressure between 250°-275°C. (482°-527°F.)		Fraction distilling at 40 mm. vacuum between 275°-300°C. (527-572°F)	Base of Crudes
			Sp. Gr.	°A.P.I	Pour Points	
VENEZUELA						
23539	-	Mene Grande	0.879	29.5	Below 5	Naphthene
998	-	-	.880	29.3	do	do
26275	Zulia	Ambrosio	.865	32.1	90	Hybrid
26276	do	La Rosa	.851	34.8	80	Intermediate
26273	do	La Concepcion	.838	37.4	90	do
26274	Falcon	El Mene	.894	26.8	80	Hybrid
UNITED STATES						
1163	Calif.	Santa Maria	.862	32.7	68	Hybrid
23515	do	Huntington Beach	.848	35.4	90	Intermediate
1141	do	Richfield	.852	34.6	92	do
1146	do	Ventura Co.	.855	34.0	82	do
646	Okla.	Healdton	.835	38.0	34	do
23434	Texas	-	.840	37.0	92	do
716	Arkansas	El Dorado	.833	38.4	91	do

A complete copy of Serial No. 2807, containing detailed tables of the distillation tests can be obtained on application to the Information Division, Bureau of Mines, Washington, D. C.

622.09
Un32mo
cop.2

STATE GEOLOGICAL SURVEY
CANCELLED

Serial No. 2808.
May, 1927.

REPORT OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

ANALYSES OF SPINDLETOP, TEXAS, CRUDE OILS

By A. J. Kraemer[1] and Peter Grandone[2]

THE LIBRARY OF THE
JUL 2 3
UNIVERSITY OF ILLINOIS

Introduction

The Bureau of Mines for a number of years has been carrying on an investigation of properties of crude oils from producing fields in the United States and has published a series of reports on different fields, including oil fields of Texas[3].

Production Data

The Spindletop field was discovered in 1901 when the pay sand was found at depths of about 800 feet. During the following twenty-five years a number of attempts were made to find a deep productive sand. All attempts were failures until a well drilled by the Yount Lee Oil Company found oil late in 1925. An intensive drilling campaign began at once, and the production of the Spindletop field increased to a daily average of 93,217 barrels in September, 1926; the present production is estimated at 66,000 barrels daily. The following table taken from the Oil and Gas Journal for February 10, 1927, shows the daily average and the total production by months for 1926.

---

[1] Associate petroleum chemist, Washington, D. C. Bureau of Mines, Department of Commerce.

[2] Junior chemist, U. S. Bureau of Mines, Bartlesville, Oklahoma.

[3] Dean, E.W., Cooke, M.B., and Bopp, C.R., Properties of typical crude oils from the producing fields of northern Texas, northern Louisiana, and Arkansas; Reports of Investigations, Bureau of Mines, Serial 2293, November, 1921.

Smith, N.A.C., Cooke, M.B., and Bauer, A.D., Properties of typical crude oils from the producing fields of southern Louisiana and southern Texas; Reports of Investigations, Bureau of Mines, Serial 2416, November, 1922.

Smith, N.A.C., Analyses of Panhandle and Big Lake, Texas, Crude Oils, Bureau of Mines Information Circular No. 6014, December, 1926.

Table 1 - Average daily and total monthly production of the Spindletop Field in 1926.

Month	Daily Average	Total for Month
January	3,372	104,532
February	5,184	145,152
March	2,642	81,902
April	2,839	85,170
May	6,587	204,197
June	4,425	132,750
July	29,390	911,090
August	78,162	2,423,022
September	93,217	2,796,510
October	82,786	2,566,366
November	85,667	2,570,310
December	90,880	2,817,280
	Total for 1926	14,838,281

According to the Oil and Gas Journal, the total production of the Spindletop field in 1925 was 420,832 barrels, or a daily average of 1153 barrels. This is in contrast to the production in 1926, of 14,838,281 barrels, or a daily average of 40,653 barrels.

Acknowledgments

Samples of crude oil mentioned in this report were obtained through the courtesy of E. E. Plumly, manager, refinery department of the Magnolia Petroleum Co. N. A. C. Smith, superintendent of the Petroleum Experiment Station of the Bureau of Mines at Bartlesville, Oklahoma, and E. C. Lane, assistant chemist, of the Bartlesville Station assisted in the preparation of this report.

Discussion of Results.

For a discussion of the methods used by the Bureau of Mines in analyzing crude oil see Bulletin 207[4]. For a discussion of the interpretation of crude oil analyses, see Serial No. 2806[5] Table I summarizes the results of these analyses by presenting some of the figures indicating physical and chemical properties of the crudes. Table 2 presents figures for the gravities of the fractions distilling at atmospheric pressure between 250° and 275°C, and also the pour points of the fractions distilling between 275° and 300°C. at 40 mm. absolute pressure. These figures indicate the "base" of a crude oil.[5]

---

[4] Bureau of Mines Bulletin 207, "The Analytical Distillation of Petroleum and its Products" by E. W. Dean and others. Obtainable from the Government Printing office, Washington, D. C. at 15 cents a copy.

[5] Smith, N.A.C. The Interpretation of Crude Oil Analyses, Reports of Investigations, Bureau of Mines, Serial No. 2806, May, 1927.

Gravities are reported in A.P.I. degrees. This is the scale formerly known in the American Petroleum industry as "Baume", based on the modulus 141.5 as distinguished from the Baume scale based on the modulus 140.0.[6]

Character of Crude Oil From the Spindletop Field

There are apparently three distinct types of crude oil in the Spindletop field, although all three belong definitely to the naphthene base (wax free) class. Analyses No. 978, 26591, and 26595 are typical of these three types of crude.

Sample 978 represents the old shallow production in this field. It is very high in sulphur, (2.31 per cent) and is deficient in gasoline, naphtha and kerosene distillate fractions. Its gravity is therefore heavy (19.7° A.P.I.), and its viscosity relatively high.

Sample 26591 represents the oil producted from 2700 to 3300 feet. This particular sample contains considerable gasoline and naphtha although the kerosene distillate fractions are entirely lacking. The gravity is therefore fairly light for a naphthene base crude, (27.7° A.P.I.) and the viscosity relatively low. Sample 26595 represents the deep production from 3300 to 5000 feet. This oil contains more gasoline and naphtha and has a lighter gravity and lower viscosity than the oil from the 3000 foot level.

These two samples are, however, similar in general character and are very different from the shallow production. This is particularly evident in the sulphur content and in the carbon residue figures. As already pointed out the shallow oil contains over 2 per cent sulphur, both the deeper oils contain less than 0.2 per cent. The carbon residue of the distillation residuum of the shallow oil is almost ten per cent, of the deep oils it is 3 per cent or less. The sulphur and carbon residue figures indicate that the shallow oil contains a much larger percentage of asphalt than do the deep oils. This not only indicates that a larger percentage of valuable products can be made from the deep oils but also that lubricating oils can be made more readily.

The two deep oils differ mainly in the gravities and viscosities of their lubricating distillates, the oil from the 4000-foot level having much lighter and less viscous distillation fractions. Ten samples of the oil typified by No. 26591 have been examined, these oils coming from depths between 2715 and 3377 feet. The character of the distillation products of these ten oils is very similar. They differ principally in their contents of gasoline and naphtha; this varies from 5 to 17 per cent. Three samples of the deep production have been examined. All three are very much alike, and Sample 26595 is typical of this production.

---

[6] A concise statement of the reasons for the general adoption of the A.P.I. gravity scale has been prepared by the American Petroleum Institute, 250 Park Ave., New York, N. Y.

Table 2 - Data showing sources of samples and some of the figures indicating physical and chemical properties

				Properties of Crude				Gasoline Fraction		Viscosity at 100°F. of Vacuum Fractions			% Carbon Residue of Residuum
Sample Number	Lease	Well	Depth Feet	°API	%S	Vis. at 100°F.	Pour Test °F.	Per cent	°API	225-250	250-275	275-300	
978	-	-	800	19.7	2.31	197	(a)	-	-	126	267	(b)	9.7
26587	Jack-Duff	2	3377	25.6	0.30	63	(a)	4.6	49.0	96	215	(b)	2.8
26588	Weed	7	3305	26.8	0.25	58	(a)	7.7	50.4	91	250	(b)	2.8
26589	Mann	4	3005	26.8	0.21	56	(a)	8.0	51.6	91	190	(b)	2.6
26590	Oakwood	6	3017	28.8	0.19	49	(a)	17.1	50.6	89	220	(b)	2.4
26591	Roche	8	3024	27.7	0.19	51	(a)	11.6	54.2	100	220	(b)	3.0
26592	Fee	12	2947	28.4	0.19	63	(a)	12.1	54.4	91	195	(b)	2.4
26593	Davis	2	2946	28.9	0.20	49	(a)	14.6	55.7	94	210	(b)	2.9
26594	Gladys City	5	2785	28.2	0.24	49	(a)	13.6	53.7	105	245	(b)	3.2
26597	McLean	15	3305	25.7	0.19	62	(a)	5.4	47.6	91	185	(b)	2.4
26599	T.&.N.O.	2	2715	29.1	0.17	48	(a)	12.7	55.7	91	220	(b)	2.5
26595	McFaddin	13	3978	30.4	0.15	46	(a)	17.6	49.0	80	145	395	1.8
26596	Fee	9	5003	29.7	0.14	51	(a)	15.7	46.7	80	145	395	2.6
26598	McLean	4	3340	29.5	0.13	46	(a)	16.6	48.3	80	150	320	2.2

(a) Below 5°F.
(b) More than 400 seconds Saybolt Universal.

Table 3

Sample Number	Lease	Well	Depth	Fraction Distilling at atmospheric pressure between 250-275°C (482-527°F)		Fraction Distilling at 40 mm. vacuum between 275-300°C (527-572°F)	Base of Crude
				Sp.Gr.	°A.P.I.	Pour Point	
973	-	-	-	0.886	28.2	below 5°F.	Naphthene
26587	Jack-Duff	2	3377	.889	27.7	do	do
26588	Weed	7	3305	.888	27.9	do	do
26589	Mann	4	3005	.887	28.0	do	do
26590	Oakwood	6	3017	.884	28.6	do	do
26591	Roche	8	3024	.889	27.7	do	do
26592	Fee	12	2947	.887	28.0	do	do
26593	Davis	2	2946	.890	27.5	do	do
26594	Gladys City	5	2785	.888	27.9	do	do
26597	McLean	15	3305	.889	27.7	do	do
26599	T.&.N.O.	2	2715	.886	28.2	do	do
26595	McFaddin	13	3978	.879	29.5	do	do
26596	Fee	9	5003	.880	29.3	do	do
26598	McLean	4	3340	.880	29.3	do	do

A complete issue of Serial No. 2808 with detailed tables can be obtained on request addressed to the Information Division, Bureau of Mines, Washington, D. C.

622.09
Un32mo
cop.2

STATE GEOLOGICAL SURVEY
CANCELLED

Serial No. 2809
May, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

COAL-MINE FATALITIES IN APRIL, 1927

THE LIBRARY OF THE
JUL 23 1928
UNIVERSITY OF ILLINOIS

By W. W. Adams[1]

Accidents at coal mines in the United States during the month of April, 1927, caused the death of 244 men; 210 occurring in bituminous mines and 34 in anthracite mines, according to reports received from State mine inspectors by the Bureau of Mines. The death rate per million tons of coal mined during the month was 5.84 for the industry as a whole, based on a production of 41,805,000 tons. The fatality rate for bituminous mines alone, based on a production of 34,674,000 tons was 6.06, while that for anthracite with a production of 7,131,000 tons was 4.77. The rate for April was somewhat higher than for the corresponding month last year, due mainly to the heavier loss of life in major explosions in April this year. In April a year ago the number of deaths per million tons was 3.06 the figure for bituminous mines being 2.87 and that for anthracite mines being 4.02.

During the first four months of 1927 812 men lost their lives from accidents in the coal-mining industry. The production of coal during these months was 230,249,000 tons, showing a death rate of 3.53 as against 4.09 for the same four months in 1926. The average rate during the four months for bituminous mines was 3.20 as compared with 4.05 a year ago; that for anthracite mines was 6.16 as compared with 4.41.

Three major disasters, that is, accidents causing the loss of five or more lives, occurred during the month. On April 2 an explosion at Cokeburg, Pennsylvania, caused the death of 6 men. On April 8 a rush of mud and gravel into a mine at Carbonado, Washington, resulted in the loss of 7 lives, and on April 30, 97 men, according to preliminary reports, lost their lives in a mine explosion at Everettville, West Virginia. No major disasters occurred in April last year, but there were seven during the preceding months of 1926, which caused the death of 189 men. For the same four months of the present year there were 4 such disasters with a resulting loss of 118 lives. Fatality rates based exclusively on these figures were 0.512 and 0.919 per million tons for 1927 and 1926 respectively.

Comparing the accident record for the period from January to April of the present year with that for the same period of 1926, a reduction is noted for falls of roof and coal, haulage, and gas or dust explosions, while a slight increase is shown for explosives. The rate for electricity remained unchanged. The comparative rates are as follows:

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

	Year 1926	Jan.-Apr. 1926	Jan.-Apr. 1927
All causes	3.790	4.088	3.527
Falls of roof and coal	1.829	1.842	1.572
Haulage	.650	.651	.595
Gas and dust explosions:			
Local explosions	.111	.082	.165
Major explosions	.525	.919	.456
Explosives	.145	.117	.156
Electricity	.143	.122	.126

FATALITY RATES FOR SMALL MINES AND LARGE MINES IN COLORADO: An interesting comparison between the fatality rates for small coal mines and those for large coal mines is contained in the annual report for 1926 by James Dalrymple, State Inspector of Coal Mines for Colorado, which has recently been published. Mr. Dalrymple's report contains two summary tables covering the years 1913 to 1925 showing the fatality rates for mines employing from 1 to 5 men, for mines employing 1 to 10 men, and for mines employing 11 men or more. According to Mr. Dalrymple, the average fataility rate for the thirteen-year period was 8.5 per thousand employees for the 1-5 group of mines, 6.7 for the 1-10 group, and 5.9 for the group of mines employing 11 or more men each. Yearly figures for the three groups were as follows:

Fatality rates per 1,000 employees and tons of coal produced per death at coal mines in Colorado.
(From pages 15 and 16 of the 1926 report of James Dalrymple, State Inspector of Coal Mines, Denver, Colorado.)

	Number of employees per mine					
	1 to 5 inclusive		1 to 10 inclusive		11 or more	
Year	Rate per 1,000 men	Tons per death	Rate per 1,000 men	Tons per death	Rate per 1,000 men	Tons per death
1913	24.4	21,199	15.6	33,452	8.44	85,688
1914	23.26	16,667	11.1	44,405	6.97	112,058
1915	6.94	50,304	3.5	122,719	5.13	136,392
1916	13.89	35,407	11.28	45,986	3.14	253,274
1917	- -	- -	- -	- -	13.73	65,551
1918	- -	- -	5.6	87,083	4.92	180,926
1919	- -	- -	2.6	166,285	7.33	113,781
1920	10.64	47,293	11.1	50,927	5.00	184,506
1921	4.59	94,422	5.29	81,576	3.63	179,576
1922	12.05	32,974	7.78	58,519	5.42	139,565
1923	7.91	56,242	6.62	71,675	4.91	160,662
1924	- -	- -	2.24	224,135	3.51	238,999
1925	15.38	27,556	10.31	45,043	4.43	196,445
Average	8.5	52,781	6.74	71,821	5.9	136,395

The foregoing figures are highly instructive not only as evidence of the greater relative hazards of mining as an occupation in the small mines of the State, but also as an indication of the higher cost, in human life, of the coal that comes from the smaller mines.

Table 1 gives comparative figures showing the number of deaths per million tons from each of the principal causes of accidents for the year 1926, and for the first four months of 1926 and 1927, respectively. Table 2 shows fatal accidents in April, 1927, classified by causes and States. Table 3 shows fatalities in January, February, March, and April, 1927 by States.

Table 4 is a comparative table showing the percentage of fatalities and the number of deaths per million tons of coal produced for each of the principal causes of accidents at both bituminous and anthracite mines, separately, for the ten-year period 1917-1926, and for the years 1925 and 1926; it also shows the average April rate over a ten-year period. A similar comparison may also be made with March 1927, with April 1926, and with April 1927.

Table 5 shows the relative standing of the coal-producing States as regards the number of deaths from accidents, underground, per million man-hours of labor performed underground. The fatality rate for the United States for all men working underground was 2.137 per million man-hours, and this rate has been weighted 100 and the rate for each State has been expressed as a certain percentage of the rate for the United States. Separate comparisons are shown for each of the principal causes of accidents underground. As a five-year period is more representative than a single year would be, the period covered in the table is for 1921 to 1925. Oklahoma is identical with the United States for all underground accidents combined, while Ohio shows 2 per cent higher and Kentucky shows 3 per cent higher. About one-half of the principal coal-producing States have lower rates for underground work than that for the United States as a whole. Pennsylvania bituminous and anthracite mines had fewer deaths in proportion to hours worked than the average for the United States in all of the causes shown except for anthracite for "miscellaneous causes" which include falls of persons, certain types of machinery, hand tools, rush of coal or gob, etc. Accidents due to falls of roof or coal show several States, which produce large quantities of coal, to be below, that is better than the average. Included in this number are Illinois, Indiana, Alabama, and Pennsylvania. Haulage showed a larger number of States below the average than above, as was the case also for gas or dust explosions, while for "miscellaneous causes" the States were about equally divided.

An analysis of the table will show the particular class of accidents from which any State is comparatively free and the classes of accidents which require special study if the rates are to be brought below the general average for the country as a whole.---Reports of Investigations, Department of Commerce, Bureau of Mines.

TABLE 1.- NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES.

	Year 1926	Jan.-Apr. 1926	Jan.-Apr. 1927
Falls of Roof & Coal	1.829	1.842	1.572
At face	1.386	1.381	1.160
In room	.238	.262	.234
On entry	.193	.199	.169
On slope	.012	- - -	.009
Haulage	.650	.651	.595
Switching and spragging	.020	.034	.004
Coupling	.008	.010	.021
Falling from trips	.030	.019	.035
Run over	.241	.233	.248
Caught between car and rib	.136	.136	.143
Caught between car and roof	.027	.015	.031
Runaway cars	.057	.024	.065
Miscellaneous	.131	.180	.048
Gas or Dust Explosions	.636	1.001	.621
Open light	.191	.063	.100
Defective safety lamp	.005	- - -	- - -
Electric arc	.081	.005	.035
Shot	.077	.194	.052
Powder explosion	.005	.005	- - -
Miscellaneous	.277	.734	.434
Explosives	.145	.117	.156
Transportation	- - -	- - -	- - -
Charging	.006	.015	.004
Suffocation	.008	.010	- - -
Drilling into old holes	.003	- - -	- - -
Striking in loose rock	- - -	- - -	- - -
Thawing	- - -	- - -	- - -
Caps & detonators	.001	.005	.004
Unguarded shots	.006	.010	.004
Returned too soon	.013	.010	.013
Premature shot	.048	.024	.035
Sparks from lamp, etc	.005	.010	.013
Delayed shots	.015	.005	.021
Shot breaking through rib	.011	.005	.031
Miscellaneous	.029	.024	.031
Electricity	.143	.122	.126
Direct contact with trolley wire	.050	.029	.052
Tools striking trolley wire	.003	.010	- - -
Contact with mining machine	.013	.005	.013
Contact with machine feed wire	.009	.015	.026
Contact with haulage motor	.003	- - -	- - -
Miscellaneous	.065	.063	.035

TABLE 2.- COAL-MINE FATALITIES DURING APRIL, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																													
Falls of roof...........	3	-	-	1	-	-	1	-	1	-	1	-	1	-	-	1	1	12	-	1	-	2	3	-	19	-	47	11	58
Falls of side...........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3	4	7
Haulage.................	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	1	-	-	9	-	23	4	27
Gas or dust explosions...	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	6	-	-	-	-	-	-	a91	-	99	8	107
Explosives..............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	-	-	-	-	-	-	2	-	6	6	12
Suffocated by mine gases.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electricity.............	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	4	-	4
Animals.................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Mining machines.........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	3	-	3
Mine fires..............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3	-	3
Other causes............	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	8	-	8
TOTAL.............	6	-	-	2	3	-	1	-	1	-	1	-	1	-	-	2	2	31	-	1	-	3	3	7	132	-	196	34	230
SHAFT																													
Persons falling.........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Objects falling.........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cages, skips............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes............	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	2
TOTAL.............	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	2
SURFACE																													
Mine cars...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	-	3	-	3
Electricity.............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Machinery...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boiler explosions.......	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Railway cars............	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Other causes............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	a7	-	8	-	8
TOTAL.............	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	8	-	12	-	12
GRAND TOTAL, April, 1927.	6	0	0	2	4	0	1	0	2	0	1	0	1	0	0	3	2	33	0	1	0	3	3	7	141	0	210	34	244
GRAND TOTAL, April, 1926.	11	0	0	3	10	3	0	1	12	0	0	0	0	0	0	8	1	30	0	4	0	3	1	0	28	0	115	33	148

a/ Explosion killed 97; 91 underground and 6 on the surface. Figures subject to revision.

TABLE 3.- COAL-MINE FATALITIES DURING 1927, BY MONTHS AND STATES

MONTH	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January..................	6	-	2	8	19	3	1	-	23	-	1	1	1	2	-	7	2	35	-	3	-	1	2	1	42	4	164	43	207
February.................	7	-	2	5	11	6	1	2	10	-	-	-	1	1	2	9	2	29	-	-	-	5	5	2	35	-	135	41	176
March....................	6	-	-	7	23	7	1	2	6	-	-	-	-	2	-	6	2	35	-	3	-	2	3	1	38	1	145	40	185
April....................	6	-	-	2	4	-	1	-	2	-	1	-	1	-	-	3	2	33	-	1	-	3	3	7	a141	-	210	34	244
TOTAL, 4 Months.......	25	0	4	22	57	16	4	4	41	0	2	1	3	5	2	25	8	132	0	7	0	11	13	11	256	5	654	158	812

a/ Explosion killed 97; 91 underground and 6 on the surface. Figures subject to revision.

TABLE 4.- AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED

Cause of accident	Per cent of total, 1917-1926	Death rates per million short tons						
		Average for 10 years 1917-1926	Year 1925	Year 1926	Average for Apr. 10 years 1917-1926	1927		1926
						Mch.	Apr.	Apr.
Bituminous Mines								
1. Falls of roof and coal	48.96	1.759	1.750	1.717	1.924	1.480	1.442	1.796
2. Underground haulage	18.18	.653	.586	.655	.702	.416	.663	.474
3. Explosions of gas or coal dust:								
Local explosions	2.91	.104	.112	.080	.097	.083	.058	.025
Major explosions	10.84	.390	.469	.565	.773	.133	2.797	- - -
4. Explosives	3.30	.118	.094	.080	.125	.033	.173	.100
5. Electricity	4.01	.144	.154	.161	.116	.150	.115	.175
6. Mining machines	1.33	.048	.067	.045	.065	.016	.087	- - -
7. Other causes underground	2.93	.105	.089	.067	.099	.033	.317	.125
8. All causes underground	92.46	3.321	3.321	3.370	3.901	2.344	5.652	2.695
9. All shaft accidents	1.73	.062	.058	.047	.060	- - -	.058	.074
10. All accidents on surface	5.81	.209	.148	.147	.241	.067	.346	.100
11. All accidents	100.00	3.592	3.527	3.564	4.202	2.411	6.056	2.869
Anthracite Mines								
1. Falls of roof and coal	42.71	2.496	2.750	2.588	2.761	3.936	2.104	2.312
2. Underground haulage	12.75	.745	.906	.612	.720	.656	.561	.974
3. Explosions of gas:								
Local explosions	6.71	.392	.421	.329	.390	.492	1.122	- - -
Major explosions	1.51	.088	.275	.247	- - -	- - -	- - -	- - -
4. Explosives	12.37	.723	.857	.588	.660	.328	.841	.365
5. Electricity	1.00	.059	.065	.024	.030	- - -	- - -	- - -
6. Other causes underground	8.18	.478	.323	.459	.435	.820	.140	.243
7. All causes underground	85.23	4.981	5.597	4.847	4.996	6.232	4.768	3.894
8. All shaft accidents	2.30	.134	.065	.094	.105	- - -	- - -	- - -
9. All accidents on surface	12.47	.729	.809	.388	.615	.328	- - -	.122
10. All accidents	100.00	5.844	6.471	5.329	5.716	6.560	4.768	4.016

TABLE 5.- Index numbers, comparing coal-mine fatality rates per 1,000,000 man-hours, underground, for different States, with the average rate for the United States (1921-1925).

Falls of roof and coal		Haulage (underground)		Gas or dust explosions		Miscellaneous (underground)		Total underground (including shaft)	
State	Index number	State	Index number	State	Index number	State	Index number	State	Index number
Alas., Calif., Ida., Nev., and Oreg.	- - -	Alas., Calif., Ida., Nev., and Oreg.	- - -	Va.	- - -	Alas., Calif., Ida., Nev., and Oreg.	- - -	S. Dak.	- - -
S. Dak.	- - -	Ga. and N.C.	- - -	Mo.	- - -	Ga. and N.C.	- - -	Texas	24
Texas	12	S. Dak.	- - -	Md.	- - -	S. Dak.	- - -	Alas., Calif., Ida., Nev., and Oreg.	27
Mich.	57	Mo.	16	Mont.	- - -	Md.	43	Kans.	64
Ill.	72	Kans.	19	Texas	- - -	Kans.	56	Iowa	68
Tenn.	72	Ark.	21	Mich.	- - -	Pa. (bit)	57	Mich.	68
Kans.	76	Texas	34	S. Dak.	- - -	Ill.	59	Pa. (bit)	70
Okla.	76	Iowa	41	Ohio	4	Iowa	76	Mo.	72
Pa. (bit)	79	Okla.	59	Iowa	4	Texas	76	Ill.	74
Ind.	80	Md.	65	N. Dak.	41	Va.	80	Md.	79
N. Dak.	80	Va.	76	Pa. (bit)	42	Ky.	93	Tenn.	81
Pa. (anth)	84	Pa. (bit)	78	Pa. (anth)	57	Tenn.	94	Pa. (anth)	88
Ala.	95	Pa. (anth)	79	Ill.	59	Ohio	99	N. Dak.	88
Iowa	95	Tenn.	86	Ky.	67	U. S. (0.340)	100	Va.	92
U. S. (1.078)	100	Ala.	92	Kans.	83	Wyo.	111	U. S. (2.137)	100
Mo.	101	U.S. (0.372)	100	Tenn.	92	Mich.	113	Okla.	100
Ga. and N.C.	110	Ohio	101	U.S. (0.347)	100	Colo.	115	Ohio	102
Ky.	114	Wash.	105	W. Va.	110	Mo.	115	Ky.	103
Md.	121	Ill.	107	Okla.	136	W. Va.	116	Ind.	111
Va.	132	Ky.	112	Colo.	158	Ala.	116	Ala.	125
Ohio	135	Ind.	116	Alas., Calif., Ida., Nev., and Oreg.	166	N. Dak.	127	Mont.	137
W. Va.	152	N. Dak.	116	Ind.	167	Pa. (Anth)	140	W. Va.	144
Ark.	160	N. Mex.	122	Wash.	202	Ind.	145	Colo.	158
Colo.	174	Mich.	124	Ark.	249	N. Mex.	155	Ark.	177
Mont.	175	Mont.	131	Ala.	258	Utah	155	Wash.	182
Wash.	177	Wyo.	145	Wyo.	948	Mont.	159	Wyo.	238
Wyo.	181	Colo.	151	N. Mex.	1,380	Okla.	186	N. Mex.	367
N. Mex.	192	W. Va.	178	Utah	2,104	Wash.	264	Utah	520
Utah	222	Utah	240	Ga. and N.C.	9,060	Ark.	324	Ga. and N.C.	1,527

622.09
Un32mo
cop.2

STATE GEOLOGICAL SURVEY
CANCELED

Serial No. 2810.
May, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

CONSUMPTION OF EXPLOSIVES IN APRIL, 1927.

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

By W. W. Adams[1]

The amount of explosives manufactured in the United States and sold in April 1927 for domestic consumption was 303,100 kegs (7,577,500 pounds) of black blasting powder, 5,030,000 pounds of permissible explosives, and 26,888,000 pounds of high explosives other than permissible. These figures are based on reports received by the Bureau of Mines, Department of Commerce, from nearly all manufacturing companies, and they include an estimate of sales by several companies that do not furnish monthly reports. Reports actually received showed sales of 297,002 kegs of black powder, 5,022,615 pounds of permissible explosives, and 25,263,571 pounds of high explosives other than permissible. The sales in April, when compared with April a year ago, represent a decrease of 35 per cent for black powder, an increase of 4 per cent for permissible explosives, and an increase of 1 per cent for other high explosives. The large reduction in sales of black blasting powder was doubtless due to the closing of many coal mines since the first of April, as coal mines consume nearly nine-tenths of all of the black powder used in the United States.

PERMISSIBLE EXPLOSIVES: The total sales of permissibles in the first four months of 1927 amounted to 22,059,000 pounds, including 22,026,833 pounds actually reported by manufacturers and an estimate to cover several companies that do not furnish monthly figures. In comparison with the same months last year, the figures for April this year show an increase of 16 per cent. Ninety-six per cent of the permissibles sold thus far in 1927 were for use in coal mining, 26 per cent being used by anthracite mines and 70 per cent by bituminous mines. The consumption of permissibles at bituminous coal mines since January 1st has averaged 75 pounds for each thousand tons of coal mined; this amount represented 28 per cent of the 268 pounds of all kinds of explosives consumed per thousand tons of bituminous coal produced. At anthracite mines 229 pounds were used for each thousand tons of anthracite coal produced, which was 31 per cent of the 744 pounds of all kinds of explosives used per thousand tons. During the first four months of 1927, the largest quantities of permissibles were used in the States of Pennsylvania, West Virginia, Alabama, Kentucky, and Illinois.

---

[1] Statistician, Bureau of Mines, Department of Commerce.

BLACK BLASTING POWDER: The quantity of black blasting powder sold during the first four months of the present year was 1,870,900 kegs, including 1,833,519 kegs sold by reporting companies and an estimate of sales by nonreporting companies. These figures represent a decrease of 9 per cent in volume of sales when compared with the same months in 1926. Of the total amount sold, 88 per cent was for coal-mining operations, (10 per cent for anthracite and 78 per cent for bituminous coal mining) while the remaining 12 per cent was used for metal mining, quarrying, construction work, and all other purposes. Of the 268 pounds of all classes of explosives used at bituminous coal mines since January for each thousand tons of coal produced, 179 pounds (67 per cent) were black blasting powder. At the anthracite mines where 744 pounds of all classes of explosives were used per thousand tons, 175 pounds (23 per cent) were black blasting powder. States consuming the largest quantities of black blasting powder during the current year are Pennsylvania, Illinois, Kentucky, Indiana, West Virginia, and Ohio, each of which has used more than 100,000 pounds.

OTHER HIGH EXPLOSIVES: The sales of high explosives other than permissibles amounted to 95,373,000 pounds during the four months January to April 1927. This amount includes 89,612,092 pounds sold by reporting companies and an estimate for several companies that do not furnish monthly reports of sales to the Bureau. The amount of high explosives sold thus far in 1927 shows an increase of 3 per cent over the same four months in 1926. Of the total amount of this class of explosives sold thus far in 1927, 12 per cent was for coal mining, (9 per cent for anthracite, and 3 per cent for bituminous coal mining) 33 per cent for metal mining, 27 per cent for quarrying and nonmetallic mineral mining, 15 per cent for railway and other construction work, and 13 per cent for all other purposes. In the mining of bituminous coal since the first of this year, 268 pounds of all kinds of explosives have been used for each thousand tons of coal produced, and of this amount 14 pounds (5 per cent) were high explosives other than permissibles. The anthracite mines used explosives at the rate of 744 pounds per thousand tons and of this amount 340 pounds (46 per cent) were "high" explosives. Pennsylvania has used a larger quantity of this class of explosives than any other State, the State's consumption during the first four months of 1927 being in excess of 14 million pounds. Michigan ranked second with a consumption of more than 6 million pounds, then California, New York, Oklahoma, Florida, Minnesota, Missouri, and Ohio, in each of which the consumption was more than 3 million pounds.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in April were more than 239,000 kegs, showed that the mills were operated to 31 per cent of their capacity in April as compared with 36 per cent in March, 54 per cent in February, and 38 per cent in April last year. The amount of explosives remaining on hand at the close of April represented 57 per cent of one month's manufacturing capacity of the mills reporting, as compared with 44 per cent at the close of April a year ago.

	April, 1926	April, 1927	Jan.-April, 1927
Capacity (Kegs)	953,583	796,083	3,184,332
Manufactured	359,330	245,837	1,394,089
Per cent of capacity.	38	31	44
Shipments	341,732	256,947	1,356,018
Per cent of capacity.	36	32	43
Sales	340,077	239,117	1,347,864
Per cent of capacity.	36	30	42
Stocks, end of month.	423,739	450,191	450,191
Per cent of capacity.	44	57	14

The following percentage figures show the extent of capacity to which mills nufacturing black powder were operated in 1924, 1925, 1926, and in the months of January, February, March, and April, 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month.

	Manufactured	Shipments	Sales	Stocks
Year 1924	41	41	41	3.8
Year 1925	38	39	38	3.2
Year 1926	40	40	39	3.6
1927				
January	54	55	56	50
February	54	47	45	58
March	36	36	38	58
April	31	32	30	57
Average, 4 months ..	44	43	42	14

Reports from 22 mills that sold more than 25 million pounds of permissibles and other high explosives in April showed that the mills were operated to 66 per cent of their capacity in April as compared with 64 per cent in March, 63 per cent in February, and 65 per cent in April last year. The amount of explosives remaining on hand at the close of April represented 17 per cent of one month's manufacturing capacity of the mills reporting, as compared with 18 per cent at the close of April a year ago.

	April, 1926	April, 1927	Jan.-Apr., 1927
Capacity (pounds)	39,153,332	38,945,000	155,780,000
Manufactured	25,605,237	25,815,776	98,529,357
Per cent of capacity .	65	66	63
Shipments	25,636,597	26,708,523	98,425,038
Per cent of capacity .	65	69	63
Sales	25,025,557	25,436,948	93,953,640
Per cent of capacity .	64	65	60
Stocks, end of month .	7,077,279	6,788,692	6,788,692
Per cent of capacity .	18	17	4.4

The percentage of full-time capacity to which mills manufacturing permissibles and other high explosives were operated in 1924, 1925, 1926, and in the months of January, February, March, and April, 1927 is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining or hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924	62	62	59	1.4
Year 1925	62	62	59	1.5
Year 1926	68	68	64	1.4
1927				
January	59	58	57	19
February	63	62	57	20
March	64	64	62	20
April	66	69	65	17
Average, 4 months ..	63	63	60	4.4

PYROTOL: During the first four months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 6,463,610 pounds of pyrotol of which 2,180,600 pounds represented shipments in April. During the corresponding four months last year the shipments amounted to 7,526,050 pounds. Most of the pyrotol shipped was for use by farmers in clearing land. Table D shows the amount of pyrotol shipped to each State in April 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal-mining operations in each State in January, February, March, and April is shown in Table C. Table D shows the quantity of pyrotol distributed in April to the various States. -- Reports of Investigations, Department of Commerce, Bureau of Mines.

TABLE A. - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during April, 1927

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	7,995	711,725	402,050
Alaska	--	234,370	44,300
Arizona	2,310	206,200	--
Arkansas	3,291	121,800	13,000
California	5,833	1,465,280	--
Colorado	1,927	312,200	32,350
Connecticut	14	179,600	--
Delaware	--	9,995	--
Florida	1,601	607,800	--
Georgia	498	194,800	--
Idaho	452	423,475	--
Illinois	5,223	647,000	38,800
Indiana	8,674	282,650	4,325
Iowa	1,833	305,850	600
Kansas	3,128	595,195	325 Rtd.
Kentucky	56,649	425,975	355,800
Louisiana	100	178,899	--
Maine	93	96,650	--
Maryland	2,083	176,750	8,350
Massachusetts	138	149,550	--
Michigan	293	1,987,100	--
Minnesota	991	1,043,240	--
Mississippi	25	106,750	--
Missouri	3,656	814,050	51
Montana	3,374	652,000	--
Nebraska	69	14,100	--
Nevada	2,000	327,325	--
New Hampshire	41	9,700	--
New Jersey	2	241,575	--
New Mexico	1,025	58,975	72,550
New York	1,048	1,483,630	--
N. Carolina	5,543	413,950	1,000
N. Dakota	859	3,432	350 Rtd.
Ohio	15,486	742,600	6,800
Oklahoma	7,297	1,055,305	6,014
Oregon	642	347,950	--
Pennsylvania	84,802	4,080,456	2,656,575
Rhode Island	14	3,500	--
S. Carolina	133	45,575	--
S. Dakota	18	97,330	--
Tennessee	9,789	396,275	16,300
Texas	11,233	904,095	50
Utah	550	707,800	22,500
Vermont	1,092	33,900	--
Virginia	6,759	267,100	116,000
Washington	3,270	860,594	43,600
West Virginia	31,203	555,325	1,116,225
Wisconsin	545	589,200	--
Wyoming	3,401	84,925	66,050
TOTAL APRIL 1927	297,002	25,263,571	5,022,615

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first four months of 1927

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	37,705	2,949,175	1,777,500
Alaska	--	715,230	54,700
Arizona	5,305	570,750	--
Arkansas	16,351	482,716	36,100
California	21,160	5,191,695	--
Colorado	18,722	1,672,715	287,300
Connecticut	75	468,450	--
Delaware	--	22,445	--
Florida	8,321	3,658,072	--
Georgia	4,494	698,000	--
Idaho	956	1,379,044	8,850
Illinois	304,511	2,249,455	951,450
Indiana	186,114	1,028,300	182,525
Iowa	52,677	733,350	1,650
Kansas	84,198	2,690,786	150,765
Kentucky	219,117	1,263,525	1,177,050
Louisiana	350	852,066	24,300
Maine	242	188,150	--
Maryland	10,411	743,650	55,400
Massachusetts	451	368,725	--
Michigan	1,394	6,601,875	--
Minnesota	3,840	3,426,258	--
Mississippi	950	449,700	--
Missouri	30,007	3,099,400	54,846
Montana	19,442	2,286,970	11,000
Nebraska	1,250	55,175	--
Nevada	11,226	1,119,375	200
New Hampshire	99	26,950	--
New Jersey	20	874,025	--
New Mexico	4,839	210,975	120,050
New York	4,161	4,281,259	15,900
N. Carolina	11,285	1,348,400	3,000
N. Dakota	7,456	43,632	5,775
Ohio	100,339	3,092,620	64,450
Oklahoma	37,614	4,012,293	63,617
Oregon	7,277	1,177,375	--
Pennsylvania	324,439	14,714,241	10,780,930
Rhode Island	67	9,650	--
S. Carolina	1,118	241,200	--
S. Dakota	211	455,485	1,300
Tennessee	36,834	1,306,175	140,650
Texas	32,636	2,468,308	2,400
Utah	5,260	2,709,100	287,700
Vermont	2,047	127,700	--
Virginia	25,628	1,277,175	511,350
Washington	11,083	2,701,127	208,275
West Virginia	170,629	1,638,125	4,701,400
Wisconsin	1,798	1,525,350	50
Wyoming	8,910	405,875	346,350
TOTAL 1st 4 MOS. 1927	1,833,519	89,612,092	22,026,833

APRIL, 1927

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs	Pounds	Pounds
Quantity used for:			
Coal mining	238,970	2,590,638	4,894,584
Metal mining	5,590	7,927,040	7,425
Quarrying and nonmetallic mineral mining	20,896	7,391,697	16,850
Railway and other construction work	19,140	3,969,494	6,445
All other purposes	12,406	3,384,702	97,311
TOTAL APRIL 1927	297,002	25,263,571	5,022,615

JANUARY TO APRIL, 1927, INCLUSIVE

Quantity used for:			
Coal mining	1,609,641	10,796,582	21,229,532
Metal mining	18,670	29,839,304	26,825
Quarrying and nonmetallic mineral mining	76,892	24,002,219	169,870
Railway and other construction work	73,516	13,434,982	55,120
All other purposes	54,800	11,539,005	545,486
TOTAL 1st 4 MOS. 1927	1,833,519	89,612,092	22,026,833

TABLE C - Quantity of explosives sold for use in COAL MINES in April 1927 by manufacturers rendering monthly reports.

(Including cumulative figures for the first four months of 1927)

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama	6,111	29,666	56,950	205,350	399,750	1,762,400
Arkansas	3,154	16,054	4,450	20,750	2,000	5,300
Colorado	1,670	14,545	11,000	65,575	23,900	266,050
Illinois	4,187	301,639	25,850	168,500	36,675	873,025
Indiana	7,541	183,343	18,750	168,800	3,825	167,125
Iowa	1,750	50,806	5,650	52,325	--	500
Kansas	2,861	81,680	23,700	244,701	425Rtd.	150,215
Kentucky	55,639	210,220	88,700	280,750	324,700	1,086,630
Maryland	1,600	8,016	1,000	7,500	4,500	38,800
Michigan	3Rtd.	1,077	6,050	16,850	--	--
Missouri	3,074	24,068	6,625	52,475	49Rtd.	26,846
Montana	2,330	12,880	100	150	--	4,000
New Mexico.....	990	1,005	3,000	5,350	72,550	119,550
North Dakota ..	835	7,239	675	29,775	350Rtd.	5,775
Ohio	12,359	89,162	22,625	162,150	3,000	23,000
Oklahoma	7,089	34,186	24,400	55,600	1,753	53,681
Penna. (Bitum.)	31,179	127,157	144,550	493,450	1,004,205	4,755,735
Tennessee	8,056	32,910	3,250	70,150	16,100	134,250
Texas	1,913	10,273	300	2,750	--	--
Utah	--	--	500	26,750	22,500	283,200
Virginia	6,166	21,288	26,600	103,350	115,800	502,500
Washington	1,798	4,924	6,100	23,700	37,100	142,500
West Virginia ..	28,367	163,370	57,500	306,550	1,102,750	4,598,125
Wyoming	3,392	6,342	5,900	22,450	66,050	306,350
Other States ..	825	1,655	3,175	23,975	45,300	65,850
Total (Bitum.).	192,883	1,433,505	547,400	2,609,726	3,281,634	15,371,407
Penna. (Anth.).	46,087	176,136	2,043,238	8,186,856	1,612,950	5,858,125
Grand Total as reported ...	238,970	1,609,641	2,590,638	10,796,582	4,894,584	21,229,532
Est. total inc. non-reporting companies	Anth.	179,800		8,717,000		5,868,000
	Bitum.	1,462,700		2,775,000		15,393,000
Total reported plus estimate..		1,642,[illegible]		11,492,000		21,261,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period April 1, 1927 to April 30, 1927

State	State Highway Department Roads	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
Alaska	--	--	--	6,000	6,000
Arizona	--	--	7,500	--	7,500
Arkansas	30,000	--	--	--	30,000
Kansas	28,500	--	--	--	28,500
Maryland	--	100	--	--	100
Michigan	--	179,650	--	--	179,650
Minnesota	20,550	498,000	--	--	518,550
Missouri	--	16,000	--	--	16,000
Montana	--	--	--	48,000	48,000
Oregon	82,500	123,500	--	36,000	242,000
S. Carolina	1,000	--	--	--	1,000
S. Dakota	20,000	--	--	--	20,000
Virginia	30,000	--	--	--	30,000
Washington	69,000	173,900	--	132,000	374,900
Wisconsin	--	678,400	--	--	678,400
Total April	281,550	1,669,550	7,500	222,000	2,180,600
Total March	249,500	1,916,860	--	108,700	2,275,060
Total February	170,750	1,020,150	--	--	1,190,900
Total January	93,000	704,050	--	20,000	817,050
Grand Total	794,800	5,310,610	7,500	350,700	6,463,610

622.09
Un 32mo
cop. 2

Serial No. 2811
June, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

THE LIBRARY OF THE
JUL 23 1930
UNIVERSITY OF ILLINOIS

THE FLOTATION OF OXIDIZED ORES.

By Thomas Varley.[1]

The literature on flotation of oxidized ores, except for patents (especially for reagents) is very sparse. The Bureau of Mines in 1916, published a circular on the subject, by Ralston and Allen.[2] The treatment of oxides by flotation was then in its infancy, but several of the most important mining companies in the Western United States and Mexico are now operating flotation plants for treating oxidized ores. The purpose of this present circular is to review the progress made and bring the subject up to date. One of the writers of the 1916 report (Mr. Allen) has been associated with some of the most important mining companies who have put into practical operation the process of flotation of oxidized ores; among these companies are the Shattuck-Arizona Copper Co., Bisbee, Arizona (now the Shattuck Denn Co.) and the San Francisco Mines of Mexico, Ltd., San Francisco Del Oro, Chihuahua, Mexico. His experience and other sources of information have been freely drawn on in preparing this paper. Mr. Ralston, assistant chief metallurgist of the Bureau of Mines, contributed many valuable suggestions and criticisms.

Sulphidizing Reagents for Oxidized Ores.

The various reagents and methods that might possibly be used for sulphidizing were summarized by Ralston and Allen[3] as follows:

> "Sulphidizing (1) by the use of hydrogen sulphide on either the dry or the wet crushed ore, (2) by the use of solutions of the various sulphides and sulpho-compounds of sodium, (3) by the use of solutions of the various sulphides and sulpho-compounds of calcium, (4) by the use of sulphur vapor, (5) by the use of a sulphureted oil, (6) with colloidal sulphur.

---

1 - Metallurgist and Superintendent, Intermountain Experiment Station, (Salt Lake City) Bureau of Mines, Department of Commerce.
2 - Ralston, O. C., and Allen, G. L., "Flotation of Oxidized Ores," Bureau of Mines, July, 1916, 12 pp. (mimeographed). Out of print.
3 - Work cited.

> "It has been found that treatment by some of these methods will form a film of sulphide over the surface of the particles of such minerals as lead carbonate or copper carbonate, whereas in other cases the mineral particles are sulphidized to the core. Other methods failed to give any results."

They also described the action of these reagents on the various ores both as to time, temperature, or heat treatments, and their effectiveness both in partial or complete sulphidization, and the metal recoveries obtained. They concluded that sodium sulphide was probably the best sulphidizing reagent tried, both with regard to manufacture or availability and to effectiveness, and that the sulphydrate of sodium (NaSH) was possibly the second best.

More recently, the Reno, Nevada, station of the U. S. Bureau of Mines has issued a paper[4] on sulphidizing reagents, particularly barium sulphide solutions. Sodium sulphide is still the most commonly used commercial sulphidizer.

Oxidized Ores

At present, the oxidized ores in general furnish the lead and copper smelters with much of the silica needed for fluxing the iron in the highly pyritiferous concentrate now made by flotation. In copper smelting, the oxidized ores furnish flux for the converters, and very often, much of the siliceous part of the charge to the furnaces producing matte. Besides using "dry" or oxidized copper ores, the copper smelters use silver ores of the same type, thereby competing with the lead smelter for this kind of siliceous flux. As the tonnage cost of the copper smelter is usually the lower, it can take ores of this type away from the lead smelter, as long as the lead content of the ore be not too great. The competition for siliceous flux has been so keen as to make profitable the closing down of favorably situated leaching plants or concentrating mills treating siliceous oxidized ores needed by the smelters.

The progress of the art of flotation has determined both the amount of iron[5] in the sulphide concentrate furnished to the smelter, and the amount of silica in the oxidized ores, for many ores of this latter type can not now be successfully treated by flotation. With advances now being made, it would appear that both the amounts of iron and silica left in concentrates will decrease, thus giving a richer feed and smaller tonnage to the copper and lead smelting furnaces.

Although the direct smelting of unconcentratable oxidized ores has considerable economic justification, it should not be overlooked that the "oxidized copper or lead" in nominally sulphide ores causes much of the loss in concentration. For instance, a well known southwestern copper concentrator has about one-fourth of the metal in its feed in an oxidized form whose recovery is very poor. In addition, oxidized ores occur in districts too far from smelters to "stand" charges for freight.

---

4 - Leaver, E. S. and Lawrence, H. M., Barium polysulphide in sulphidizing oxidized ores for flotation: Bureau of Mines Serial 2698, August, 1925.

5 - Oldright, G. L., Developments in concentration of copper ores: Mining and Metallurgy, November, 1925.

The importance of recovering oxide as well as sulphide minerals, particularly in semi-oxidized lead and copper ores, has resulted in making sulphidization a part of the treatment scheme in some milling plants, described below.

Oxidized Ores -- General Properties
A Rational Method of Developing a Flotation Process

Oxidized ores may be considered as ore whose components have undergone a change in chemical composition by natural weathering, usually from the sulphide form. The decomposition of minerals and changes in chemical components depend on the conditions and agencies involved. In weathering under common conditions, the sulphides oxidize to sulphates, and in turn, over long periods of time, under the influence of other agencies, the sulphates may change to carbonates and oxides--whichever may be the most stable form under existing circumstances. Thus in a deposit of oxidized ores there may be all gradations in transformation of minerals, from true sulphides to true oxides. Under more unusual chemical conditions, rarer compounds may be formed, some of which will be tabulated later.

It should now be clear that the forms in which the mineral constituents are present in an ore have an important bearing upon the method employed for their recovery. As each metal forms its own special compounds, and exhibits reactions peculiar to itself, it becomes necessary to understand thoroughly the exact form of the mineral constituents, and their association with each other, as well as their association with the waste material of the ores.

As would be expected, the properties of the oxidized part of an iron ore body usually will be found to vary greatly. It is difficult to obtain a mill feed of oxidized material that will be uniform, or to make even general statements as to properties such material may possess. In addition to variations in the composition of the valuable constituents, the gangue minerals have weathered along with them and undergone similar changes in form, thereby causing further complications. For example, in treating ores having feldspar present, kaolinization and sericitization of the feldspar often causes an abundance of "natural slime," which in turn causes troubles familiar even in gravity concentration. The flotation operator is not only troubled by the mechanical qualities of oxidized ores, that may cause losses in the tailing or dilution of the concentrate, but in addition has to face the varying amount of surface alteration and oxidation of the minerals he is trying to float. The gangue minerals possess varying flotative and adsorptive properties. Soluble salts exert a very striking influence, particularly those that form sulphides which are partly insoluble in the dilute alkaline circuits usually employed. The flotation man can not afford to overlook any solvent that may etch or slimy precipitate that may coat the valuable minerals. At best, the presence of a large amount of soluble salts usually means a very large consumption of flotation reagents.

No one would attempt extensive experimental work on an ore with a view of separating the metals from each other, as well as the gangue material, without chemical analyses of the ore to learn the metallic contents thereof. Investigations by the Bureau of Mines on complex ores over a period of years has definitely shown that it is equally as important, if not more so, to make a mineralogical and size analysis by microscopic examination and other means of dissection. If a mechanical method of separation is to be used, such as by gravity or by flotation concentration one must know the following:

(1) All minerals present in the ore together with their physical characteristics.

(2) The degree of crushing necessary to liberate the desired minerals.

(3) The association and approximate quantity of such valuable minerals.

(4) The association of the valuable minerals with the gangue material.

It may not be possible to free 100 per cent of each mineral at any stated degree of crushing, but the economic degree of crushing can be readily determined.

Chemical analyses give sparse information on the physical characteristics of the several minerals, especially whether their surfaces are tarnished with substances that prevent contact with the sulphidizing or other solution.

As an example of the advisability of determining all the minerals present, some preliminary work recently done on an oxidized ore may be cited. This oxidized silver-lead ore had been "tested" in a commercial laboratory with poor recoveries; the "tests" by flotation showed only about 55 per cent recovery of the lead, and less by gravity methods. Microscopic examination showed that the ore contained an appreciable quantity of plumbojarosite[6] a hydrous sulphate of lead and iron, (perhaps $PbO.3Fe_2O_3.6H_2O$). Preliminary experiments on the action of Na_2S in varying quantities up to 20 pounds per ton of ore, indicated that the plumbojarosite did not sulphidize, and subsequently did not float. In flotation tests 87 per cent of the lead carbonate was recovered, and only 26 per cent of the plumbojarosite.

In this particular instance, the poor recovery of metal was directly traceable to a mineral whose presence had not been suspected, and which was not amenable to the treatment used. It has been popularly assumed that an oxidized lead ore contains lead in the form of the carbonate (cerussite) or the sulphate (anglesite). With this in mind, the better-known oxidized lead minerals are herewith tabulated.

---

6 - For description of this mineral see U. S. Geol. Survey Bull. 509, pp. 81-82.

Oxidized Lead Minerals

	Symbol. (Dana)	Specific gravity Dana.	Int.Crit. Tab.a
Lead carbonate – cerussite	$PbCO_3$	6.46–6.574	6.6
Basic lead carbonate – hydrocerussite	$2PbCO_3.Pb(OH)_2$	6.14	6.14
Phosgenite – chlorocarbonate	$PbCO_3.PbCl_3$	6–6.09	6.13
Plattnerite – lead dioxide	PbO_2	8.5	9.37
Wulfenite – lead molybdate	$PbMoO_4$	6.7	6.7
Massicot – lead monoxide	PbO	8.0	8.0
Minium	Pb_3O_4	4.6	9.1
Barysilite	$3PbO.2SiO_2$	6.11–6.55	6.72
Ganomalite	$3PbO.2(Ca,Mn)O.3SiO_2$	5.74	5.74
Melanotekite	$2PbO.Fe_2O_3.2SiO_2$	5.73	5.73
Anglesite	$PbSO_4$	6.12–6.39	6.2
Leadhillite	$4PbO.SO_3.2CO_2.H_2O$	6.26–6.44	6.5
Lenarkite	Pb_2SO_5	6.3–6.4	6.92
Caledonite	$(Pb\ Cu)SO_4.(Pb\ Cu)(OH)_3$	6.4	
Linarite	$(Pb\ Cu)SO_4.(Pb\ Cu)(OH)_2$	5.3–5.45	5.4
Plumbojarosite	$PbO.3Fe_2O_3.4SO_3.6H_2O$	No gravity given	3.63
Corkite – hydrous phosphate and sulphate of Pb and Fe.		do.	4.2
Beaverite	$CuO.PbO.Fe_2O_3.2SO_3.4H_2O$	do.	4.36
Vanadinite	$(PbCl)Pb_4V_3O_{12}$	6.66–7.23	6.86
Descloizite	$R_2V_2O_8.R(OH)_2$ (Emp.)	5.9–6.2	6.0
Dechenite	PbV_2O_6	5.6–5.81	
Pyromorphite	$3Pb_3P_2O_8.PbCl_2$	6.5–7.1	6.8
Crocoite	$PbCrO_4$	5.9–6.1	6.3

a/ International Critical Tables.

Oxidized Lead Ores

Presumably most lead ores were originally sulphides and by oxidation, carbonation, and other changes, the sulphur compounds of lead have been transformed into other minerals. The three oxides, massicot (PbO), minium (Pb_3O_4), and plattnerite (PbO_2), are common though not abundant. Lead carbonate (cerussite, $PbCO_3$), is a common and abundant mineral and perhaps the one most amenable to sulphidizing and flotation treatment. Lead chloride (cotunnite, $PbCl_2$) and other oxychlorides are found but not in abundance. Lead sulphate (anglesite, $PbSO_4$), is a common oxidation derivative of galena. Chromates, vanadates, arsenates, and phosphates are quite common though they usually occur in limited amount.

The frequent association of lead ores with those of zinc makes it necessary to take advantage of every physical and chemical peculiarity of the minerals of each in order to effect a separation. Fortunately lead carbonate, the common lead mineral of the oxidized variety, is very susceptible to sulphidation while the zinc silicate, which often occurs with it, is not. Hence, when the lead mineral is sulphidized it can be floated from the zinc, and the zinc content is frequently recovered by subsequent treatment. Unfortunately, some of the other fairly common oxidized lead minerals are not so readily floated, and among these might be mentioned anglesite and plumbojarosite.

Perhaps the most dependable treatment for oxidized ores, especially where anglesite (lead sulphate) is present, is stage crushing at comparatively coarse mesh and gravity concentration (tabling) for the removal of coarse heavy minerals. Regrinding, sulphidizing and flotation can be used subsequently to recover more of the valuable minerals not saved by the tables.

Some oxidized ores contain acid salts which are objectionable in flotation treatment, especially as consumers of sodium sulphide or other sulphidizing agents. A preliminary washing will remedy this trouble. One large mill in Mexico crushes the ore and washes it in Dorr classifiers and thickeners to remove soluble salts, the cost of such a treatment being less than that of the reagent loss with unwashed ore.

In sum, when lead is present in oxidized ores as carbonate, it can be readily sulphidized and subsequently recovered by flotation. Why some of the other common and rarer oxidized lead minerals are not floatable is not known. Some examples of what is being accomplished in milling practice are shown under the head of "Operating Plants."

The flotation of oxidized ores of zinc is almost an unexplored field.

Theory for the Sulphide Filming of Lead Carbonate

Sodium sulphide hydrolyzes according to the following equations:

(1) $Na_2S + H_2O = NaOH + NaHS$

$PbCO_3$ is soluble in NaOH, as follows:

(2) $PbCO_3 + 3Na(OH) = NaHPbO_2 + Na_2CO_3 + H_2O$

(3) $NaHPbO_2 + NaHS = \underline{PbS} + 2NaOH$

Combining Nos. 1, 2, and 3, we have -

(4) $Na_2S + PbCO_3 = \underline{PbS} + Na_2CO_3$

PbS is insoluble in dilute acids or alkalies and only a film of it need be formed.

While the mechanism of sulphide "filming" is not completely understood, it is quite possible that the three reactions given above represent the individual steps, but it is quite certain that the fourth reaction represents the beginning and end products. Reaction No. 1 has been discussed more fully by Allen.[7]

OXIDIZED ORES OF GOLD AND SILVER

Gold

Although gold is one of the scarcer elements, it is widely diffused in Nature. It is usually found associated with other metals in ores, sometimes as the major economic metal, and in amounts gradually diminishing to quantities negligible for recovery. It occurs principally in the free state, as tellurides, or alloyed with other metals, but always mixed with other minerals, pyrite and quartz being especially frequent associates. Clarke[8] states that "Its connection with pyrite is so intimate that some writers have argued in favor of its existence as gold sulphide,**** No unmistakable gold sulphide has yet been found as a definite mineral species. **** The common compounds of gold are exceedingly unstable, and the metal separates from them with the greatest ease."

The method of recovery of gold as applied to any particular ore depends entirely on its association with other minerals. When associated with pyrite, flotation will often be a successful mode of recovery, but if pyrite be "dropped" by flotation, the recovery of gold in such cases, may suffer. When it occurs as finely divided metallic particles which are liberated from the gangue during grinding and are not included in, or coated by oxide minerals, it is also recoverable by flotation. Ores which contain all the gold as separate microscopic metallic particles are rare, but ores which contain a commercial percentage of the gold in such condition are fairly common.

---

7 - Allen, G. L., Chem. and Met. Eng., Feb. 15, 1919.
8 - Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 770, p.657.

Silver

Silver, like gold, is widely diffused in Nature. Blende, galena, and the pyritic ores almost invariably contain it. Argentiferous gelena, "silver-lead ore," is one of the chief sources of this metal. Silver occurs in numerous compounds of the sulphides, the tellurides, the sulphosalts, and as halogen compounds. Native silver is common though not found in abundant quantities. Among the sulphosalts tetrahedrite is particularly noticeable as being a carrier of silver.

In the oxidized ores the halogen group predominates, cerargyrite (horn silver, AgCl) being the most common; bromyrite, AgBr, and iodyrite, AgI, being less common. Other compounds of this group occur in intricate mineral association. Many conflicting statements have been made on the floatability of silver chloride, some claiming it is easily floated, and others that it is floatable only with great difficulty. Some plants floating this mineral have found it very difficult to save a good percentage. Freshly precipitated silver chloride may be readily floated, which calls attention to the importance of experimental work in flotation with pure natural minerals, rather than with fresh chemical precipitates.

Only one oxidized compound of silver is known to exist in nature--namely, argentojarosite,[9] a sulphate of ferric iron and silver. Exact knowledge of the form of silver in oxidized ores is often wanting, and this lack of information may cause the ore to be improperly treated.

Oxidized Copper Minerals

The oxidized minerals of copper are numerous and represent a wide range of composition. Copper is found not only as oxide, but also among other compounds also as carbonates, silicates, sulphates, phosphates, arsenates, and an oxychloride. The metal is easily oxidizable, and is also easily reduced; it therefore occurs both as native copper and in its many compounds.

In general, the conditions under which oxidized lead ores are floated will be favorable to the successful recovery of copper from oxidized copper ores. As with lead ores, it is very important to determine what minerals are present in an ore before flotation is applied. Thus when mixtures of silicate and other oxide copper minerals are present, under ordinary sulphidizing circuit conditions, the silicate resists sulphidizing and flotation. Mixtures of sulphides and oxides of copper have been recovered together by sulphidizing the oxides prior to flotation treatment, as will be seen. What oxidized minerals of the accompanying list would be amenable to such treatment could only be determined by direct experimentation upon the pure minerals themselves. Clean metallic copper can be recovered by flotation, but most of the other minerals on the list require sulphide filming to render them floatable.

---

[9] - Journal of the Washington Academy of Science, vol. 13, 1923, p. 233.

The following copper minerals are more or less common in oxidized ores.

Oxide Copper Minerals

	Symbol.	Specific gravity.
Malachite	$CuCO_3 \cdot Cu(OH)_2$	3.9 - 4.03
Azurite	$2CuCO_3 \cdot Cu(OH)_2$	3.77 - 3.83
Aurichalcite	$2(Zn, Cu)CO_3 \cdot 3(Cu, Zn)OH_2$	3.54 - 3.64
Cuprite	Cu_2O	5.85 - 6.15
Tenorite	CuO	5.82 - 6.25
Atacamite	$Cu_2ClH_3O_3$	3.75 - 3.77
Olivenite	$Cu_3As_2O_8 \cdot Cu(OH)_2$	4.1 - 4.4
Pseudomalachinite	$Cu_3P_2O_8 \cdot 3Cu(OH)_2$	3.4 - 4.4
Dioptase	H_2CuSiO_4	3.28 - 3.35
Chrysocolla	$CuSiO_3 + 2H_2O$	2.0 - 2.23
Copper	Cu	8.8 - 8.9

Flotation Plants Treating Oxidized Ores

In gathering the information on operating plants attempts were made to get in touch with every plant known to be treating oxidized ores by flotation. A few are not described in this paper, either on account of failure of the companies to report their practice, or not having come to the writer's attention.

Plants Treating Oxidized Lead Ores

The San Francisco Mines Co., Ltd. at Parral, Chihuahua, Mexico, is just about to begin operation (December, 1926) of a 250-ton flotation plant for oxidized lead ores. The plant is under the supervision of Glenn L. Allen and no doubt will, in a general way, parallel operations of other up-to-date plants.

Eureka Holly Mill, Eureka, Nev.:- This small mill is treating 75 tons of ore daily. The ore averages about 10 per cent lead and 3 ounces of silver per ton; the occasional small amounts of zinc have not given any difficulty in mill treatment.

The lead is present in the ore in about the following proportions: 25 per cent as lead sulphate ($PbSO_4$) and 75 per cent as lead carbonate ($PbCO_3$). The silver is presumably present as silver chloride and sulphide.

The ore is crushed to 16 mesh and then concentrated on Wilfley tables which produce a finished concentrate assaying about 55 per cent lead and 20 ounces of silver. This concentrate represents about 50 per cent of the total lead and silver in the crude ore.

The tailing from the tables is then sent to a ball mill with a classifier in closed circuit. At the head of the ball mill reagents are added equivalent to 1 pound of sodium sulphide and 0.5 pound of "reconstructed" oil per ton of ore.

The ore leaving the ball mill will all pass a 40-mesh screen; about 35 to 40 per cent will pass a minus 200-mesh screen. The pulp density is about 25 per cent solids.

The following reagents are added to the classifier overflow before the pulp goes to the flotation machines: N.T.U. shale oil, a product from the N.T.U. Company's plant at Santa Maria, Calif., Barrett Co. No. 4 reconstructed mixture, sodium sulphide, about 1 pound per ton of ore, and thiocarbanilide, approximately 0.01 pound per ton. The latter is added to assist the silver recovery.

The pulp then passes to four Janney flotation machines in series, from which finished concentrate is removed, except provision is made to return the concentrate from the last cell to the head of the circuit for re-treatment, if it is found necessary to do so. Water at ordinary temperatures is used.

The tailing from the flotation machine is tabled, and a small amount of concentrate recovered which is a finished product. The tailing from the tables goes to waste.

The over-all recovery of the lead is 70 to 75 per cent, and of the silver, 65 to 70 per cent. The combined finished concentrate averages 45 to 50 per cent lead, 15 to 20 ounces of silver and $2 in gold per ton, 11 to 17 per cent "insoluble," 5 to 14 per cent iron, and about 1 per cent zinc.

Santa Barbara Carbonate Ore Mill, Parral, Chihuahua.- The mill of the Compania Minera Ascaro, S. A., at Parral, Chihuahua, Mexico, is treating 700 tons of carbonate ore daily by a combination of gravity concentration and flotation. It has been described in detail by Parsons.[10] The ore assays approximately Pb 5.0, Cu 0.3, Fe 6.0, insoluble 70.0, CaO, S.0, and S 1.0 per cent with 0.09 ounces of gold and 4.0 ounces of silver per ton. The lead is mostly in the form of carbonate; very little sulphide or sulphate of lead is present.

The ore is crushed to 10 mesh for gravity concentration (tabling), and reground for flotation to 2 per cent plus 65 mesh and 60 per cent minus 200 mesh.

---

10 - Parsons, A. B., Selective flotation at Parral: Eng. and Min. Journal, vol. 122, Oct. 23, 1926, pp. 644-648.

A modified Elmore type of flotation machine is used. The flotation reagents used per ton of ore are 3 pounds sodium sulphide, 3 pounds sodium silicate, 2 pounds Mexican crude oil, 0.1 pound cresylic acid, and 0.1 pound No. 5 pine oil. The ratio of liquid to solids in flotation feed is 2.5 to 1.

The natural temperature of pulp approximate 75° F. The average grade of concentrate made is: Gold, 0.5 oz., silver, 27.0 oz., and lead, 40.0%.

This product is by weight about one-half gravity (table) concentrate and one-half flotation concentrate. Reports do not give recoveries of metal content, but it is understood that they correspond closely with those of other mills treating the same type of ores by similar methods.

In June, 1924, the Grand Central Mining Co. began to treat old tailing dumps at their plant near Fairbank, Ariz. After trying cyanidation and volatilization, a flotation system was installed and proved successful. The writer visited the plant in May, 1925. It was operating on the tailing material, treating about 130 tons daily. Tonnage was not weighed but estimated from cars which carried the material from ponds to the mill. The material goes into a hopper from the cars, and from thence is fed to a pug mill with plenty of water added. The harder lumps are crushed in a mill by quartzite river pebbles used in lieu of steel balls.

The material was reported to contain 4.5 per cent lead, 3.5 ounces of silver, and from 80 cents to $1 per ton in gold. It also contains a small percentage (about 0.60 per cent) of copper. No screen analyses were available, although from examination it was estimated that the material from the pug mill would all pass a 65-mesh screen.

Sodium sulphide is fed into the ball mill at the rate of 5 pounds per ton of feed (ore) and xanthate at the rate of 0.1 pound per ton. Pine oil and wood creosote equivalent to 0.2 pound per ton are fed into a closed-circuit flotation machine which is used as a conditioner and emulsifier. From this machine, the pulp is fed to two other flotation machines, half the feed to each. The concentrate from these machines is shipped direct without recleaning. The flotation concentrate was reported as assaying 35 per cent to 60 per cent lead, 18 to 24 ounces of silver per ton, and $5 to $10 in gold. Recovery of 90 per cent of the lead and 65 per cent of the silver is claimed.

The plant is cheaply constructed and cheaply operated, as the life of the enterprise is limited to a few years, at which time all the old tailing will have been treated. The simplicity of treatment and apparent efficiency is creditable.

Shattuck-Denn Mining Co. Concentrator, Bisbee, Arizona.- One of the first important mills to treat lead carbonate ore by flotation was the Shattuck mill designed and constructed by Glenn L. Allen during the war and placed in operation in August, 1918. Being almost the first of its kind it required a year of tuning up before recoveries were regarded as satisfactory, and it operated till Dec. 1920 when it was closed down on account of low lead prices and mine difficulties. Allen has described its details[11] and reference should be made to his paper. During that period it treated about 300 wet tons daily with the following results:

	Gold	Silver	Lead
Heading	.0619 oz.	5.489 oz.	5.22%
Tailing	.0224	2.272	.535
Concentrate	.276	22.99	30.70
Per cent recovery	69.42	65.06	91.35

The ratio of concentration was 6.418 to one. On the 1920 flow sheet when the lead content of the combined concentrates exceeded 30 per cent, the recoveries decreased in proportion.

The ore milled in 1919 and 1920 by the Shattuck Company was treated as a by-product of the mine in determining the mining cost of mill ore, and with the price of silver and lead ruling in those years showed a profit, until the slump in the price of lead the last of 1920.

As the market prices of lead and copper were unattractive during the years 1921 and 1922, there was no production from the Shattuck mine of either lead or copper ores, and the concentrator was not operated in those years. As the decline in price of silver after termination of the Pittman Act in June, 1923, more than offset the profit that had previously been obtained from concentrating lead ores, experimental work was begun in the hope of improving results sufficiently to overcome the reduction in price of silver. The research work was done by the Shattuck Company, the Minerals Separation Company, and the Southwestern Engineering Corporation, and by March, 1925, it was believed that more satisfactory results could be obtained by straight flotation of the low-grade lead-carbonate ore than had been obtained previously by tabling and flotation.

The details about the revised mill have been published by the management,[12] and the following notes are from that paper.

Operation was resumed at the concentrator on April 14, 1925, on a revised flow sheet, and have continued up to date on flotation only, eliminating the screening ahead of tabling, the primary tables, the re-grinding, the secondary tables, the Allen cones, pumping for re-grinding and the sand tables; also eliminating the thickening of the pulp and agitating ahead of flotation.

---

[11] - Eng. & Min. Jour., Oct. 16, 1920.

[12] - McGrath, T. and Stanley, I. E., Flotation of lead carbonate ores of the Warren Mining District, Bisbee, Ariz.: Arizona Mining Jour., vol. 10, Sept. 15, 1926, Mining Cong. Jour., vol. 12, Oct., 1926.

The fine ore is fed to two 64-1/2 inch ball mills, where it is ground in closed circuit with drag classifiers to 95% through 100 mesh. The pulp from the classifiers is delivered to a rougher flotation machine, from which a primary gold-silver-lead concentrate is run to thickening tanks for filtering. About 45% of the gold and silver and 20% of the lead is obtained in this concentrate.

The tailing from the rougher passes to three primary flotation machines, where a primary lead-silver-gold concentrate is taken and sent to the thickening tanks. The tailing is retreated by flotation, yielding a secondary concentrate which is pumped to the head of the three primary machines. The tailing from the secondary machine goes to waste.

The principal factors that govern satisfactory recoveries are: fine grinding, proper alkalinity and density of flotation pulp, selective flotation, proper reagents of certain proportions, and skilled operators.

The character of the water used is very important. The best results are obtained when the total alkalinity is approximately 13 grains per gallon. An excess of iron in the water is detrimental both to lead and silver recovery; if copper is in solution, the silver recovery is poor.

The tailing water can be re-used by settling with lime in increasing amount until a stage is reached when the lime has no effect. The water also can be settled for re-use several times by adding leach waters from tailing dumps containing ferrous sulphate in solution. The only water now reclaimed is that obtained from the thickener tanks. The amount of new water used is approximately 800 gallons per ton of ore.

The use of reclaimed water settled with ferrous sulphate seemed to improve the lead recoveries but lower the silver recoveries, eventually to where the loss in silver more than offset the gain in water saved and additional lead recovered.

The reagents that give best recoveries of gold, silver and lead are sodium sulphide, sodium silicate, xanthate, Lewis tar and No. 70 frothing oil. The quantity required of each varies continually, and the recovery depends upon the skill of the operators. The average quantity of the reagents used per ton of ore is about as follows: Sodium sulphide, 2.0 lb., sodium silicate, 2.0 lb., xanthate, 0.1 lb., Lewis tar, 1.0 lb., No. 70 oil, .75 lb. The sodium silicate, xanthate and part of the tar and oil are put into the ball mills, the sodium sulphide and remainder of tar and oil at tail end of the rougher flotation machine.

Typical results are as follows:

	Gold Oz. per ton	Silver Oz. per ton	Lead Per Cent	Ratio
Heading	.107	6.84	6.10	-
Tailing	.022	1.65	.55	-
Recovery	81.6 a	79.1 a	92.30	-
Concentrate	.823	40.19	39.02	6.932

a/ Per cent.

The recoveries of all metals are about the same on a concentrate up to 40% lead, but it is difficult to produce a combined concentrate higher than 45% lead. The loss of lead in tailing gradually increases with lead content of feed, but this increase in loss of lead depends more on the amount of lead sulphate in the ore than on the grade of ore or concentrate.

As a result of the work since April, 1925, the management believes that-

(1) Equal recoveries can be obtained by straight flotation, and better recoveries by selective flotation, and as cheaply, as by tabling and flotation.

(2) Recovery of the gold and silver does not depend upon grinding finer than 100 mesh, but upon proper reagents.

(3) Delay after the application of sodium sulphide, to allow time for sulphidizing before flotation, is not necessary.

(4) Thickening of pulp ahead of flotation is not necessary, but may improve results.

(5) Use of sodium silicate reduces the amount of sodium sulphide required, and makes a higher grade concentrate.

(6) Siliceous ore is particularly adapted to sulphidizing by sodium sulphide. Ores of high iron content consume a large amount of sodium sulphide. Lead ores containing manganese are difficult to float. The higher the manganese the greater the difficulty.

(7) Violent agitation is not necessary. Machines which depend as much upon mechanical agitation as air, are the best for flotation of lead carbonate ores, especially in taking off the lead after sulphidizing. An excess of air seems to be detrimental to good lead recoveries.

Plant at Broken Hill, New South Wales, Australia. Flotation After Treatment in a Furnace.- Some oxidized compounds can be changed by furnacing methods to their original composition, or to other compounds that may be floated. An example of the use of this method for a lead ore is described below.

The metallurgical staff at Broken Hill were operating a plant treating about 600 tons per week[13] of weathered slime from an old concentrator.

The feed contained in per cent:

Lead as PbS	2.30	Copper	0.06
Lead as $PbSO_4$	16.40	Silver	0.04
Zinc as ZnS	12.10	CO_2	0.40
Zinc as $ZnSO_4$	2.10	SiO_2 + "insoluble"	40.00
Iron	3.70	S as sulphite	7.44
Manganese	2.19	S as sulphate	3.58
Lime	1.42	O_2 as SO_4	7.12
Magnesia	0.10	Total	98.95

The ore was heated in a straight-line 4-hearth furnace to between 680 and 720° C. The furnace was fired with producer gas, and only 13 pounds of charcoal (coal was not satisfactory) were required to reduce the $PbSO_4$ to PbS, as there was already a considerable amount of wood fiber in the old slime. It was found that below 680° C. there was no reduction to PbS, and that above 750°, although the $PbSO_4$ was reduced, the ore fused and stuck to the rabble teeth, and could not be subsequently floated. It was found necessary to quench the ore quickly to avoid reoxidation. About 65 per cent of the lead sulphate was reduced to lead sulphide.

The ore was floated by selective flotation. For reagents, a "sulphur solution," eucalytus oil, and acid were used. The pulp was heated to 125° F. The products made were a lead concentrate containing about 55 per cent lead, a zinc middling and a "clean residue."

Plants Treating Gold-Silver Ores

That the recovery of gold and silver by flotation is important is shown by the 1925 figures,[14] when 484,924 tons of gold-silver ore was treated by flotation in the United States. The percentage of division, or quantity, of the oxidized and sulphide varieties could not be estimated; the greater tonnage, however, was no doubt of the sulphide variety.

When flotation is applied to gold and silver ores, it is often supplemented by gravity concentration (tabling) or cyanidation, and when appreciable amounts of free gold and silver are present may be preceded by amalgamation. At times flotation concentrate has been treated with cyanide as at the Tomboy mine in Colorado, and at other times flotation tailing has been cyanided.[15]

---

[13] – Nevett, R. D., The development of a process for the treatment of weathered slime at Broken Hill: Chem. Eng. and Mining Review, June 5, 1925.

[14] – Varley, Thomas, Consumption of flotation reagents, 1925: Bureau of Mines Reports of Investigations, Serial No. 2777.

[15] – Atckison, E. J., Flotation of semi-oxidized silver ore: Mining and Scientific Press, Apr. 27, 1918.

Plants Treating Oxidized Copper Ores

A number of flotation plants have treated oxidized ores of copper on a commercial scale. Among these might be mentioned the plants at Magma, Arizona, Kennecott, Alaska, and at Katanga, South Africa, but the operating data obtained are not available. Much experimental work has been done on oxidized ores by engineering firms like the Southwestern Engineering Co. and the General Engineering Co. Some of the work by the Eureka Metallurgical Co. has been done on a semicommercial scale, and so might be noted here.[16] The variety of ores treated will be found of interest.

If metallic copper is considered as an oxidized mineral, the fact should ne noted[17] that some of the Lake Superior ores of this type have been floated. Metallic copper also has been formed in oxidized ores by artificial means, as by precipitation from solution with iron at Hurley, New Mexico,[18] or by furnacing method as at Bwana M'Kubwa, Northern Rhodesia.[19] Where the metal is not too greatly altered, it may be floated; of course, other methods as leaching also may be used.

There is no doubt that one of the greatest metallurgical sources of loss of copper lies in the concentration of the semioxidized ores, as the larger portion of the oxidized minerals of copper present is usually lost in the tailing. The improvement made at Ajo, Arizona, is therefore of sufficient importance to quote at length a statement from one of the company technologists.

The Flotation of Oxidized and Carbonate Copper Ores at Ajo, Arizona[20]

"At the commencement of operations at the flotation concentrator of the New Cornelia Copper Company at Ajo, January 1924, it was anticipated that, for a period of two years, the flotation feed would contain 1.5% total copper, of which 1.3% would be sulphide and 0.2% nonsulphide copper. At the expiration of the two-year period, the ore would possibly be maintained at 0.1% nonsulphide.

"Experimental work in the 500-ton pilot plant had indicated that a sulphide recovery of 85.00% should be maintained. For the initial experimental operation, a sulphide area had been opened up, the sulphide copper content of which consisted of clean chalcopyrite mineral with a small percentage of oxidized bornite.

---

[16] - Hahn, Albert W., Flotation of oxidized ores: Mining and Metallurgy, September, 1923, p. 465.

[17] - Benedict, C. H., Six-cent copper from Calumet and Hecla tailing: Eng. and Min. Jour., vol. 117, Feb. 16, 1924, p. 284.

[18] - Rickard, T. A., The Chino enterprise: Eng. and Min. Jour., vol. 117, 1924, pp. 13-20.

[19] - Walker, Geo. L., Bwana M'Kubwa, a potential copper producer: Eng. and Min. Jour., vol. 119, May 23, 1925, p. 837.

[20] - By G. A. Wallerstedt, Chief Chemist, New Cornelia Copper Company.

"After the first six months of operation it was found that the average flotation feed contained a much larger percentage of bornite and oxidized rusty mineral, with the result that the sulphide recovery was lowered. By careful survey of the mine pit operation, and other data at hand, the following points were decided:

"First: that the nonsulphide copper content of the flotation feed would persist in a much higher ratio to the sulphide content than had been anticipated, and that the sulphide itself would contain a much greater percentage of bornite than originally expected.

"Second: that this condition would continue until mine operations had extended completely into the sulphide zone.

"Third: that a treatment should be evolved to save as large a portion of the oxidized mineral as possible, without lowering the recovery of clean sulphide.

"The reagents used in the flotation plant at this time were coal tar, potassium xanthate, and G.N.S. No. 5 pine oil. Since the mill water, as pumped from the well, had an alkalinity of eight grains per U. S. gallon, no addition of lime or its equivalent was necessary. Laboratory experiments with C. P. crystalline sodium sulphide gave indifferent results, but when commercial fused 62 to 64% sodium sulphide was used, the results from the tests immediately improved.

"After several series of laboratory tests, a section test in the concentrator, using sodium sulphide, calcium polysulphide, coal tar, pine oil, and potassium xanthate, was recommended. The sodium sulphide was made up in 10% solution from commercial fused material. The calcium polysulphide was also used in a 10% solution, made from lime and sulphur at the concentrator. Tests to determine the best point at which to add reagent, were conducted; the final practice as adopted was the addition of sodium sulphide at the rod-mill discharge before classification. The use of calcium polysulphide was eliminated. From this point, the results obtained in the experimental section of the flotation plant, using sodium sulphide, were invariably higher than the results obtained in sections using the regular treatment.

"The chief difficulty experienced, in operating with sodium sulphide, was due to the excessive alkalinity built up in flotation circuit, caused by the regular addition of sodium sulphide. This resulted in a poor flotation pulp condition. Classification and flotation were erratic. It was necessary to add some reagent to reduce the alkalinity to a normal percentage. The discard solution from the leaching plant, containing a high ferrous sulphate content and a slight acidity, was an available waste product. This was added to the flotation tailings before entering the tailings pond, which resulted in the return water to the mill circuit being reduced to an alkalinity of six to seven grains per U. S. gallon. By careful control the alkalinity in the mill circuit has been maintained at nine to ten grains per U. S. gallon.

"In December 1924, sodium sulphide was adopted as a reagent in the entire flotation plant. In the following table a comparison of results for the period of Jan. 9, 1924 to December 1, 1924, is made with the month of May 1926, in which month the total oxide content of the flotation heads is very nearly the same as for the first period.

	Jan. 9 to Dec. 1 1924 without sodium sulphide	May 1926 with sodium sulphide	Increase with sodium sulphide
	Per cent	Per cent	Per cent
Heads;			
Total copper	1.606	1.700	
Oxide copper	0.387	0.344	
Sulphide copper.	1.219	1.356	
Tailing:			
Total copper	0.407	0.244	
Oxide copper	0.277	0.157	
Sulphide copper.	0.130	0.087	
Concentrate:			
Total copper	36.634	32.443	
Grinding:			
Per cent of ore on 65 mesh . .	7.4	12.6	
Recoveries:			
Total copper	75.523	86.242	10.719
Oxide copper	30.768	56,570	25.802
Sulphide copper.	89.716	93.814	4.098
Gold	63.482	86.819	23.337
Silver	73.585	83.573	9.988
Reagents (pounds per ton ore):			
Coal tar	0.489	0.603	
Pine oil, G.N.S. No. 5	0.125	0.303	
Potassium xanthate	0.003	0.062	
Sodium sulphide.	none	2.820	

"The only variation in the use of sodium sulphide was adopted in April, 1926, when it was found by a series of tests that from the time the ore was dumped into the bins after being sprayed, a very appreciable amount of oxidation took place in the interval before the ore reached the fine grinding mills. This was overcome by spraying the ore with 5% sodium sulphide as it was conveyed from the roll plant, the last stage of crushing, to the flotation ore bins. This procedure has been decidedly a success in offsetting further oxidation of the ore.

"Metallurgically, the recovery of both oxidized and sulphide copper has been increased, the gold and silver recovery has also been increased, and concurrently, the amount of copper, gold, and silver left in the tailings is decidedly lower. Owing to the better flotation condition of the pulp, it has been possible to increase the mill tonnage three hundred tons per day. The flotation feed is now held at 88.00% through 65-mesh screen instead of 94.00% through 65-mesh screen.

"From an economic standpoint this additional recovery has been accomplished at a decided profit over the additional reagent cost incurred through the use of sodium sulphide."

CONCLUSIONS

General

In comparing the flotation of oxidized ores in plant practice, with the flotation of the sulphides, it appears that the former has borrowed the new reagents developed largely in the flotation of sulphides, and to these now adds sodium sulphide as almost the only sulphidizing agent. There is a tendency to still use the heavier oils and tars to a greater extent than the latest practice for sulphide ores would deem feasible. The special reagents for oxidized ores developed in the various laboratories, as indicated by flotation patents, do not appear as yet to have been widely adopted in plant practice. However, special frothing "oils" are used in some plants. Sodium silicate is used to some extent, probably to assist in excluding the slime present in most oxidized ores.

A large tonnage of oxidized ore is being smelted directly. The economy of continuing this practice will depend largely on the balance between iron and silica in the smelter charges, as well as on the improvements in the art of floating oxidized ore itself. The amount of iron present in turn will depend largely upon developments in the concentration of the sulphide ores.

In looking over the developments in the flotation of oxidized ores since a fair start was obtained, say about 1916, the writer feels that although new reagents have been tried, the percentage of the oxidized material recovered in usual plant practice has not greatly increased. The growth, it would be felt, is more an increase in tonnage treated than in percentage of metals recovered. For the greater part, in plant practice the developments in the flotation of sulphide ores have been followed rather than new developments found by research work on the oxidized ores, and the oxidized valuable minerals, themselves.

The extent to which rarer minerals of oxidized ores occur, other than those commonly known has not, perhaps, received due consideration. Since the chemistry and mechanism of sulphidizing lead carbonate, for instance, appears to be relatively exact, failure to secure high recoveries when treating an oxidized lead ore by sulphidizing and flotation may be taken as an indication that the ore contains constituents that are either not sulphidized at all or to such a slight extent as to have little effect on their floatability.

Comparatively little is known regarding the possibilities of sulphidizing many of the minerals listed and what is perhaps a more pertinent fact, the content of these minerals in oxidized ores from various localities. Knowledge of this character is essential to intelligent treatment of any ore, and can be acquired only by intensive study and the utilization of the correct methods of procedure.

From a consideration of the information along this line that has been made available by modern ore-dressing microscopy, there is little reason except inertia to be offered for lack of knowledge of the nature of the mineralogical composition and physical characteristics of the metal-bearing constituents of ores and of tailings.

Work done at the U. S. Bureau of Mines experiment station, Salt Lake City, on pure sulphide minerals[21] has been productive of fundamental data on the mechanism of some of the commoner reagents used in flotation. In-so-far as is known, little or no work of a similar character has been applied to ascertaining the effect of sulphidizing or other treatment on the various pure oxidized minerals.

The extent to which difficulties are encountered in the treatment of oxidized ores is reflected by mineral loss in the final tailing. It is logical to investigate this product thoroughly in order to ascertain the form of the lost mineral, and also whether the mineral loss is due to a coating of foreign material, such as iron oxide and clay, or of some alteration product of the mineral itself that isolates the valuable material from contact with the reagents. Also when any reagents are added that seem to be promising for chemical reasons, a good idea may be obtained from close study as to why they do or do not function as expected. For instance in the filming of a mineral, it may be learned whether the film does not form or whether it does not adhere after it is formed. Reasoning from chemical or physical hypotheses may indicate the proper procedure to obtain a sufficiently stable film to enable the mineral to float.

It is hoped that these suggestions will prove helpful in indicating a rational line along which to attack the problem of treating oxidized ores. If the properties of ores may be learned as indicated, and the minerals lost be likewise determined, if these lost minerals are among those that may be floated when they are pure by reagents, a satisfactory method should be developed of preventing much of the losses from oxidized ores.

---

[21] - Tucker, E. L. and Head, R. E., Effect of cyanogen compounds on floatability of pure sulphide minerals, Part I: Trans. A.I.M.E., vol. 73, 1926, pp. 354-371.
Tucker, E. L., Gates, J. F. and Head, R. E., Effect of cyanogen compounds on floatability of pure sulphide minerals, Part II: Trans. A.I.M.E., vol. 73, 1926, pp. 372-380.
Gates and Jacobsen, Some flotation fundamentals and their practical application: Univ. of Utah Research Bull. No. 16, 1925, p. 38.

Alkalinity of Pulps

In summarizing the operations of the plants, most all of them pay considerable attention to the alkalinity of the pulp. Excess lime seems to have considerable effect upon the flotation conditions. The alkalinity is usually kept from nine to thirteen grains per U. S. gallon.

Some of the operators use ferrous sulphate ($FeSO_4$) to reduce and control the alkalinity of the pulps. Other reagents where the SO_4 radical can readily be utilized could be used.

Pulp Density

The pulp densities are usually kept about 25 per cent solids. They vary however in some cases from 20 to 28 per cent solids.

Grinding

Practically all of the plants crush the ore to all pass a 65-mesh screen. Most of them crush to about 95 per cent through 100-mesh and 60 per cent through 200-mesh.

Sulphidizing Reagents

The common sulphidizing agent is sodium sulphide of the commercial grade. This varies in quantities from one to five pounds, commonly used in amounts proportional to the amount of material to be sulphidized. Calcium polysulphide has been used in some cases but its use has been reported as being discontinued.

The method of adding the sodium sulphide varies greatly. Some prefer to add the material to the ball mills or other grinding medium while others add in solution form at different points in the flow line. It is generally conceded, however, that the reagent should have some little time to act upon the ore before being passed to the flotation circuits. This time may be arrived at by some experimental work.

Flotation Reagents

Most operators use a relative crude oil in small amounts which seems to stabilize the froth. Sodium silicate is added in some cases. It seems to assist the sodium sulphide somewhat, for the plants reporting its use also report the use of smaller quantities of sodium sulphide. Xanthate seems to steady and balance the flotation froth. However, some of the plants do not use this reagent.

Reconstructed oils of various kinds are made. In most cases they are used especially to assist in the silver recoveries. Thiocarbanalid seems to improve the silver recovery in some cases.

Frothing Agents

Cresylic acid, hardwood creosote, and pine oil seem to be used mostly as frothing agents. Refined coal-tar products are used at some plants in place of the other frothing agents.

While it would be difficult to forecast any reagents that might be best suited to a particular ore, it might be well for experimentors to try the oils and reagents which are in common use, for this particular type of flotation. - Report of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un32mo
cop. 2

Serial No. 2812.
June, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

PRECIPITATION OF LEAD AND COPPER FROM SOLUTION ON SPONGE IRON

THE LIBRARY OF THE
JUL 23 1956
UNIVERSITY OF ILLINOIS

By

G. L. Oldright[1], H. E. Keyes[2], Virgil Miller[3] and W. A. Sloan[4].

Introduction

The Bureau of Mines in its investigation on manufacture[5] and utilization of sponge iron, has conducted in cooperation with mine operators in the West a large amount of experimental work on the precipitation of lead and copper from leach solutions by use of sponge iron as a precipitant. The work on lead solutions was conducted by the Intermountain Experiment Station at Salt Lake City, Utah, and that on copper by the Southwest Station at Tucson, Arizona. In these experiments, laboratory size apparatus was developed in which complete precipitation of lead, and also of copper, at a rapid rate was attained.

The results of these experiments are briefly described in this report. A more complete report will be issued in the future by the Bureau of Mines.

Object of Experiments.

As sponge iron is much like porous, coarse sand, it is a very tempting material to use as a precipitant of metals, in place of coarse scrap iron, which in comparison is awkward to handle and exposes only a small amount of surface to pregnant liquors. The following experiments are largely a record of the behavior of sponge iron as a precipitant of lead and copper, under laboratory conditions, comparable to those that would be present in a commercial plant in attempting to obtain maximum contact of surface between solution and precipitant. Physically, the study is largely one of the rates of diffusion of the metal ions in the solutions, and through the metallic coatings surrounding the sponge-iron particles. The practical objectives are to remove completely the valuable metals from solution, and at the same time obtain a precipitate of good grade. In order to fulfill this latter requirement, the precipitant should be almost completely consumed. These practical ends are usually attained by having the two substances involved pass each other countercurrently--that is, in such a manner as to have the strongest precipitant in contact with the most impoverished solution, and vice versa.

---

[1] Assoc. Metallurgist.
[2] Hydrometallurgist.
[3] Asst. Metallurgist.
[4] Asst. Chemist.
[5] Williams, C. E., and others, The Production of Sponge Iron, Bull. 273, 1927 (In course of publication.)

Experiments with Lead Solutions.

In nearly all methods involving the leaching of lead from its ores, this metal has been dissolved into solution as the chloride, and concentrated liquors have been employed. The solubility of lead under such conditions is comparatively small at best; the hot pregnant liquors from which the metal is to be precipitated are nearly saturated with respect to lead. Only a very small amount of acid is used. Therefore, there was no need to learn the behavior of the sponge iron in precipitating lead from solutions of widely differing composition, but rather to learn under what conditions, and with what mechanisms, this precipitation might be most readily carried out.

An historical sketch was accordingly prepared, with a sufficient number of references to enable an investigator to familiarize himself with past practice. Then a series of experiments were conducted, with quantitative results, so that the future designer might obtain ideas as to what specifications had to be met in order to satisfy the physical and chemical properties of the lead on precipitating it in apparatus of varying types.

It was found that the solutions should be heated to 60°C. in order to precipitate the lead in less than an hour, if the solution were stirred vigorously. Solutions colder than this, however, would not usually be employed in plant operation. It was learned that the sponge-iron particles more thickly coated with lead, would "ball" if stirred too vigorously. The presence of more than five times the quantity of iron required chemically to replace the lead had very little effect on shortening the time needed for complete precipitation, although the particles poorer in lead did not have this tendency to unite. The rate of precipitation varied directly as the amount of lead left in solution, when the amount of iron added was just that required stoichiometrically to replace the lead.

In order to avoid the agglomeration of the lead-coated sponge-iron particles that is caused by stirring, pregnant lead liquors were percolated upward or downward through beds of sponge iron. It was found that only thin beds could be employed, if the iron were to be nearly all utilized, as the precipitated lead occupies more volume than did the iron, and thus made the bed impervious to the passage of solutions. It was found possible to precipitate all the lead from solution by having a large excess of sponge iron present, but enrichment of this precipitate by subsequent exposure to an excess of fresh rich solution was difficult. A maximum exposure of 10 hours was required for the iron inside the lead-coated particles to become completely replaced. Porous and pure varieties of sponge iron were found to react much faster than those having the opposite qualities. Attempts to utilize beds of sponge iron a few inches thick by giving them freer opportunity to expand in V-shaped receptacles, were unsuccessful.

Attempts were made to so separate the particles that they would not agglomerate even when a rapid rate of diffusion was given the liquor by various forms of mechanical stirring. Dropping the iron into the solution in V launders feeding a slowly operated stirring tank, and the use of ribbed or plain drums was found to "ball" the precipitate. The sponge iron was found to oxidize rapidly when agitated in the solution by blowing air through a porous diaphragm.

It was finally found that freedom from "balling" could be insured by slowly rabbling sponge iron downward over a series of superimposed trays placed in a cylindrical tank, and allowing the pregnant solution to flow upward countercurrently against the passage of the iron. Products containing more than 80 per cent lead were made, while at the same time the liquors running from the machine were barren of lead. This type of apparatus was then tried with commercial solutions and found to operate successfully.

Experiments with Copper Solutions.

Copper-sulphate solutions have been used containing widely differing amounts of copper and acid. The use of iron as a precipitant for copper is very old, and machines of many types have been employed. For these reasons, in contrast to the work on lead, the chief interest lay in learning the behavior of copper on precipitating from various solutions. Afterwards several types of mechanisms were noted in which it would be feasible to carry out the precipitation by sponge iron, and experiments were made using one apparatus.

The behavior of sponge iron made from various ores and by different processes was compared. In regard to the amount of iron that should be used, it was found that an excess of 7.5 per cent of metallic iron over that required stoichiometrically to precipitate the copper was usually sufficient, and that there was but little advantage to be gained by adding an excess of over 15 per cent. Whether the sponge iron was added in stages or all at the start, made little difference.

The temperature increased very rapidly on precipitating the copper, and was difficult to control, as often over 80 per cent of the metal was replaced from solution in 2 to 4 minutes. As the rate of precipitation increased sharply with increase of temperature, a carefully standardized procedure was needed to give comparable results.

The content of the solution in both copper and acid affected the rate of precipitation. An increase in acidity decreased the rate of copper precipitation in the richer copper solutions, but increased it in the poorer solutions, when the amount of sponge iron present was 7.5 per cent in excess of the chemical equivalent. On computing the solubility of the metallic iron of the sponge iron in the presence of acid and copper, it was found that the amount of metallic iron dissolved increased with an increase in acidity for the richer copper solution, and decreased with an increase in acidity for the solutions that were poorer in copper. There was evidently an interrelationship between the rate of dissolving of the iron, and the rate of precipitation of the copper. (The rate of dissolving of the sponge iron varied considerably with the kind of iron used.)

The measurement of the rate of precipitation of the copper was again rendered difficult by the fact that the copper precipitated was the difference between the amount that had been chemically replaced by the iron and that which had been dissolved. The rate of dissolving of pure copper in pure sulphuric acid solutions in the presence of air was examined, as were also the effect of the addition of ferrous sulphate, and of the exclusion of air. The amount of copper dissolved by acid with the air excluded was practically nothing. When air was admitted, the addition of ferrous sulphate slowed down the rate of dissolving from what it was with acid alone.

It was concluded that the dissolving was due to the direct atmospheric oxidation of metallic copper, with the subsequent dissolving of the oxide in sulphuric acid, rather than through the agency of ferric salts. The air was sucked in by the rapidly rotating impellers, during the precipitation, the quantity of air dissolved in the original solution being negligible.

When a constant amount of metallic cement copper was added to a solution agitated in an open beaker, the more acidic the solution, the greater was the percentage of copper dissolved. With a constant ratio of three parts of metallic copper to two parts of acid, increasing the acidity of the solution increased the number of grams of copper dissolved, but in general decreased the percentage precipitated of the total copper present. The number of grams of copper dissolved per minute for a given percentage of acid was also approximately constant up to the time all the acid was neutralized. With this same 3 to 2 ratio between copper and acid, the fastest rate of dissolving of the copper was at an acid content of between 10 and 16 grams per liter. The amount of air admitted and the size of the bubbles were found to influence greatly the rate of dissolving of the copper.

All of the above data were applicable to the design of machines in which the copper could be precipitated by batch methods, with some few additional data on rates of settling. Where the resolution of the copper on account of the admission of air was not serious, the metal could be nearly completely precipitated in 15 to 25 minutes with an amount of sponge iron 7.5 per cent in excess of the theoretical equivalent.

The great difficulty in designing a continuous precipitation system is to obtain countercurrent passage of the precipitant and solution. A scheme involving alternate agitators and thickeners was suggested, along with other plans. Any design involves a compromise in the time spent for agitation to insure close contact between the solution and the precipitant, and that spent for settling the partly used sponge iron plus precipitated metal from the solution, to effect the countercurrent passage of the two. In the precipitator that has a series of horizontal trays over which the sponge iron was rabbled downward, and over which the solution ascended, for the work on lead the compromise was all in favor of settling to make the metals go downward, since the solution could not be agitated violently on account of "balling" the lead.

The same type of multiple-tray precipitator was tried for the precipitation of the copper. It was found that the capacity of the apparatus could be fixed at a constant volume of liquor for solutions containing more copper than say 0.5 per cent. The machine operated satisfactorily mechanically, but modifications to the design were suggested, to afford better contact between the sponge iron and the solution. As the sponge copper does not "ball" it may be kept in suspension by agitation. The rate of settling of all of the copper except a little "float" is rapid. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un32mo
cop.2

Serial No. 2813
June, 1927.

REPORTS OF INVESTIGATIONS

BUREAU OF MINES - DEPARTMENT OF COMMERCE

THE "BREATHING" ACTION OF ELECTRICAL EQUIPMENT.

THE LIBRARY OF THE
JUL 2 3
UNIVERSITY OF ILLINOIS

By L. C. Ilsley[1]

Nearly every piece of electrical equipment used in mines "breathes." In other words, motors, controllers, rheostats, switches, and other similar equipment, even though encased in seemingly tight compartments, breathe in the atmosphere that surrounds them.

As the apparatus is used, the temperature of metallic parts is changed generally in positive direction through the heat by friction and the heat due to the electric current. When the apparatus is idle it gradually cools down to the temperature of the surrounding atmosphere.

This increase of temperature during operation and return to normal temperature when operation stops alternately raises and lowers the temperature of the atmosphere within the compartments which, in strict accordance with Charles' law -

$$\frac{T}{T'} = \frac{V}{V'}$$

will expand or contract in proportion to any given temperature change.

As compartments are not gas-tight, such expansion and contraction will force the atmosphere out of the compartment upon expansion and suck the surrounding atmosphere into the compartment during contraction, hence the term "breathing."

Investigators[2] of explosion-proof equipment have recognized that such an interchange would take place and have designed their equipment to safeguard possible explosions within the compartments.

---

1 - Electrical engineer, Bureau of Mines, Department of Commerce.

2 - von Beyling, Versuche zwecks Erprobung der Schlagwetter-sicherheit besonders geschutzter elektrischer Motoren und Apparate sowie zur Ermittlung geeigneter Schutzvorrichtungen fur solche Betriebsmittel. Ausgefuhrt auf der berggewerk-schaftlichen Versuchstrecke in Gelsenkirchen, 1906, 89 pp.

In its testing work under permissible schedules, the U. S. Bureau of Mines has always assumed that such an interchange of atmosphere from the inside to the outside of a compartment might take place, and has based its tests upon this supposition. In its routine testing for permissibility the Bureau does not await the slow filling of the compartment with an explosive mixture which might take hours, days, or even weeks, depending upon the tightness of the compartment, the temperature rise during operation, and the percentage of gas in the surrounding atmosphere, but to save time immediately fills the compartment with an explosive atmosphere by mechanical means. The explosive mixture within the compartment is then ignited by the electric spark. The process is repeated many times; in some cases as many as 50 tests are made on a single compartment. Thus the Bureau in a comparatively short time obtains a very good idea of the worst that could happen to a properly maintained compartment if it should "breathe" in an explosive mixture and that mixture should be exploded by normal or abnormal sparking or arcing of electric circuit within the compartment; and further proves the adequacy of the casing flanges were this cycle of events to be repeated many times.

EXPERIMENTAL TESTS

In order to have some experimental data on actual apparatus, the Bureau recently conducted breathing tests on two pieces of equipment which were sent for examination under Schedule 2B. The units tested were a motor and the switch and fuse compartment used with the motor. This particular motor was of the open type installed in an explosion-proof type casing surrounding the motor. The switch and fuse were enclosed in an explosion-proof type compartment.

The test procedure was to place each unit in a gallery, which was then filled with Pittsburgh natural gas so as to insure an explosive mixture of gas about the compartment. This would represent a condition that might take place in a mine, if a dangerous quantity of gas should accumulate where the equipment was installed. The motor was operated during the day and shut down during the night. This cycle was continued several days until in two series of tests the motor compartment had breathed in sufficient gas to give an explosion within the motor housing. During the test, especially at night, the gallery lost some of the gas and this loss was made up by adding more gas to the gallery.

Curves a, b, and c of Figure 1 cover the two series of tests on the motor compartment. Curve a shows the amount of gas in the gallery. (Note the period of no gas when equipment was being moved to a different gallery.) Curve b shows the gas in the motor compartment which gradually increased by the breathing action of the compartment. When the gas within the compartment increased to 6 per cent an explosion took place. This explosion was not transmitted to the gas surrounding the motor compartment, which shows that the explosion-proof qualities of that compartment had protected it; in fact, in previous tests when the compartment had been filled with gas, the compartment

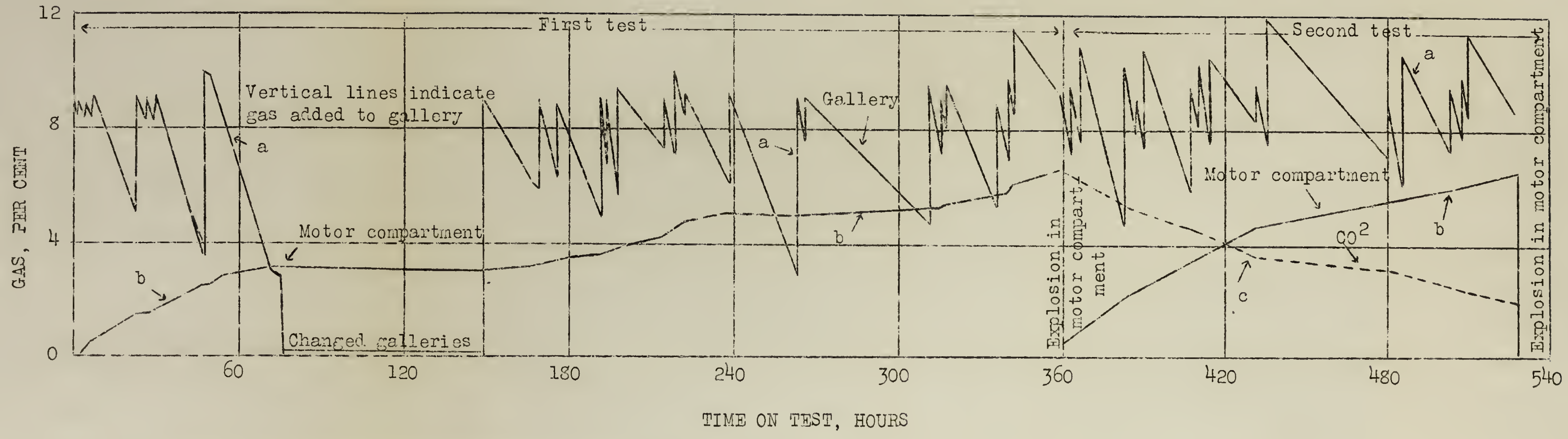


Fig. 1.- RATE OF DIFFUSION OF GAS INTO COMPARTMENT SURROUNDING MOTOR.

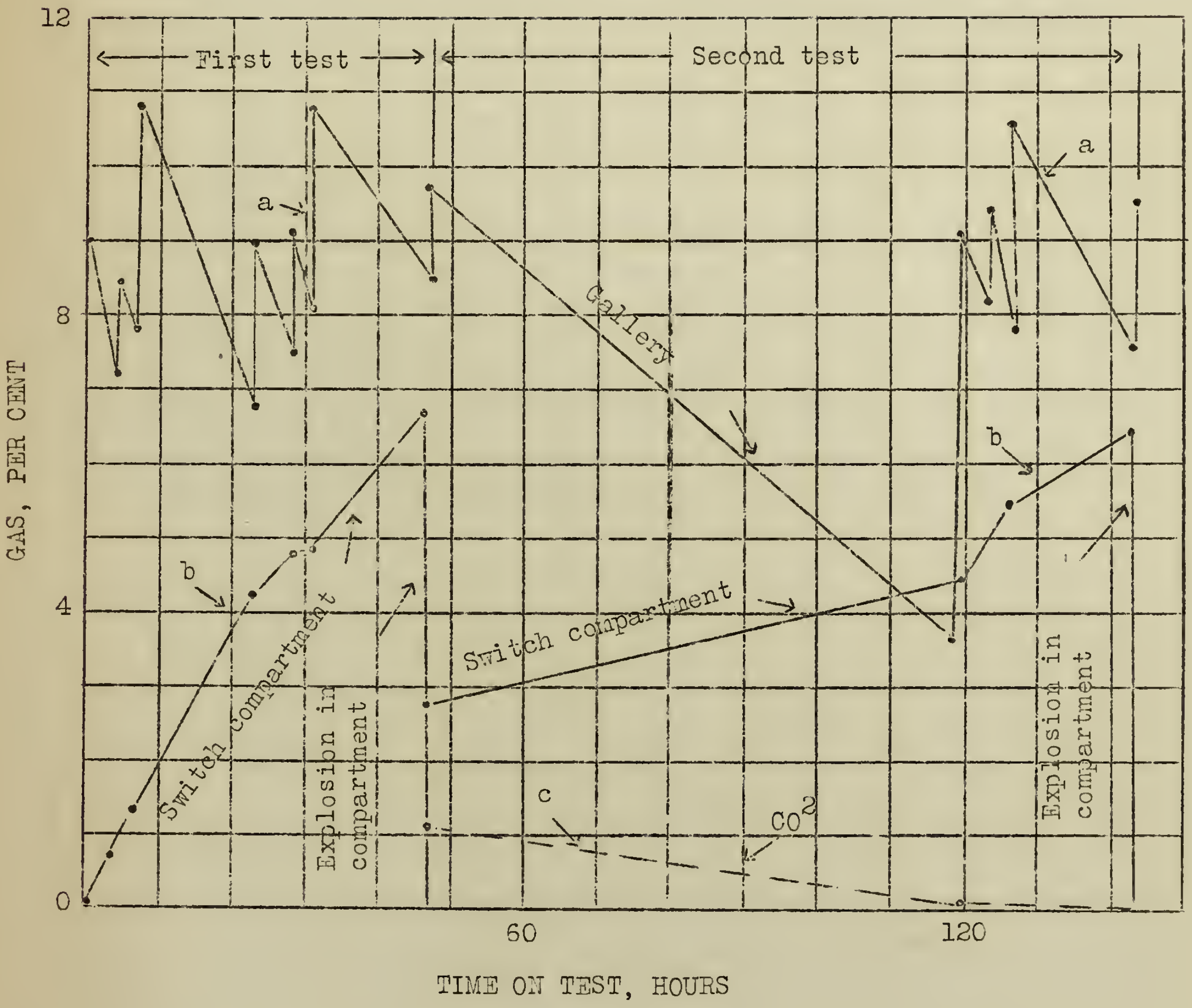


Fig. 2.- RATE OF DIFFUSION OF GAS INTO SWITCH AND FUSE COMPARTMENT.

had been proved satisfactory in retaining flames. Curve c shows the carbon dioxide resulting from the burning of the gas by the explosion. This gradually decreased as the breathing went on during the second tests.

Figure 2 shows similar data for the switch and fuse compartment. About the only difference is that the switch was operated only a few times at the higher percentages of gas, and then to obtain a spark for setting off the explosive mixture within the compartment. Two series of tests were run. Explosions were obtained in shorter time on this compartment because the breathing action was greater, even with no rotating parts within the compartment.

DISCUSSION OF TEST RESULTS

The actual test results only bear out the well-known physical fact previously stated. The rate with which the compartments were filled by the breathing action is interesting because it has a bearing on the probable frequency of explosion within a compartment were it to be surrounded with methane in a mine. This series of tests emphasizes the necessity of using permissible equipment and the desirability of having all makes of equipment used at the face workings proved by test. The value of the test is to ascertain by trial (1) that there are no openings overlooked; (2) that flanges and joints are properly designed; and (3) that the strength of the casings will withstand explosion within a compartment. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un32mo
cop. 2

Serial No. 2814
June, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

FATALITIES IN THE CALIFORNIA PETROLEUM INDUSTRY DURING THE CALENDAR YEAR 1926.

By H. C. Miller[1]

This paper is one of a series on accidents in oil fields. Papers previously published by the Bureau of Mines on accidents in California oil fields include Serial 2611[2], Serial 2772[3], and Technical Paper 382[4].

The total number of fatalities in the petroleum industry of California in 1926 has again decreased as compared with the total for the previous year. There were 53 fatalities in 1926. For the year 1925, there were 59; in 1924, there were 61; and in 1923, the number was 75. This gradual yet certain reduction in the total number of fatal accidents, year by year, apparently indicates that good results are being obtained through accident prevention work in the petroleum industry of the State. But the goal for which all are striving is yet a long way off, because every preventable industrial death is proof that the highest attainable condition of safe and efficient development has not been reached. Every department, every official, and every employee of the petroleum industry of the State has some responsibility in this matter.

The engineers of the Bureau of Mines believe that detailed reports of fatal accidents are of assistance to those engaged in safety work, not only in California but wherever oil is produced, transported, refined, and marketed. Although every accident is brought about by some peculiar combination of circumstances, the possibility of preventing the recurrence of similar general conditions in other fields and other places makes the study of past records valuable.

With this in mind, the fatal accidents occurring in 1926 in the petroleum industry in California have been listed for each of the four major divisions of the industry. Fatalities on board tankers and oil barges, and any fatalities "off shore" are not included in this report. Each accident has been discussed in turn with reference to its immediate cause, under the heading of the division in which it occurred.

---

1 - Petroleum engineer, Bureau of Mines, Department of Commerce.

2 - Miller, H. C. Fatalities in the California oil fields, Serial 2611, Bureau of Mines, 1925.

3 - Miller, H. C. Fatalities in the California petroleum industry during 1925, Serial 2772, Bureau of Mines, 1926.

4 - Miller, H. C. and Steidel, C. E. Accidents in the California petroleum industry in 1923, Tech. Paper 382, Bureau of Mines, 1926, 30 pages.

THE LIBRARY OF THE
JUL 2 3

The data upon which this report is based were obtained from the files of the Industrial Accident Commission of the State of California, augmented in a few cases by correspondence with officials and safety engineers of those companies in which the fatalities occurred.

The number of fatalities by divisions of the industry for the years 1925 and 1926 with percentages of decrease for 1926 are given in Table 1.

Table 1. Fatalities by Divisions of the California Petroleum Industry for the Calendar Years 1925 and 1926 with Percentage of Decrease for 1926.

	Number of fatalities		Percentage of decrease
	1925	1926	
All divisions	59	53	10.17
Drilling and producing	31	25	19.35
Pipe line and transportation	3	10	233.34*
Refineries	15	13	13.33
Sales and marketing	10	5	50.00

* Increase.

The number of fatalities in the drilling and producing division have decreased each year since 1923, during which year there were 59 fatalities in this division alone. A reduction of 57.63 per cent in four years in the number of fatalities in a division in which the hazards are above the average occupational hazards of the petroleum industry shows clearly what concentrated effort towards the elimination of accidents in the oil industry will accomplish. This splendid record made in the reduction of the number of fatal injuries in the drilling and producing division can be attributed mainly to three causes: (1) Enforcement of the General Petroleum Industry Safety Orders for Drilling and Producing issued by the Industrial Accident Commission of the State of California[5]; (2) to the spirit with which the company managements and operators are furthering the safety movement and supporting those whose efforts are being directed towards eliminating accidents and (3) to the sympathetic cooperation of the men in the oil fields for whose benefit the safety movement was originally instigated and for whom it is being more and more generally fostered.

Two disasters which received much publicity, occurred during the latter part of December, 1926. One of these occurred in the pipe line and transportation division and the other in the refinery division of the California petroleum industry. These two catastrophes, taking a toll of ten lives, were responsible mainly for the increase in the number of fatalities within these two divisions.

Summary of Fatalities in the Drilling and Producing Division

Noticeable progress is being made in the reduction of the number of fatalities in the drilling and producing division of the California petroleum industry. A reduction of 19.35 per cent in the number of fatal accidents for

---

5 - General petroleum industry safety orders for drilling and production: issued by the Industrial Accident Commission of the State of California, 1924.

the year 1926 was made although there was a slight increase in drilling activity within the state. The monthly average number of wells drilling in 1926 was 422 as against 417 in 1925.

Table 2 shows the number of men killed in the drilling and producing fields of California for the years 1923 to 1926, inclusive, the amount of oil produced in California each year and the corresponding production fatality figure expressed in millions of barrels of oil.

Table 2. Fatalities, Oil Production and Production per Fatality in the California Oil Fields by Calendar Years, 1923 to 1926, inclusive.

Year	Number killed	Oil production (Barrels)	Production per fatality (Millions of barrels)
1923	59	263,728,895	4.46
1924	44	230,063,117	5.23
1925	31	230,147,342	7.43
1926	25	224,117,013	8.96
Average	39.75	237,014,092	5.96

Well drilling was the cause of 48 per cent of the fatalities in the drilling and producing division in 1926. The same percentage held true in 1925, but the number of drilling wells per fatality at drilling wells (based on the monthly average of wells being drilled) was 36.8 in 1926 as compared with 27.8 in 1925, an improvement of 9 wells drilled per fatality. These figures, perhaps more than any others, show conclusively the progress that safety work has made in the drilling and producing division, for the work at drilling wells is without doubt the most hazardous within that branch of the industry.

The producing department showed a slight increase in its ratio of fatalities to number of producing wells in 1926 as compared with 1925. There were 6 fatalities at producing wells in 1926 against 5 in 1925. At the same time, the monthly average of producing wells dropped from 11,393 in 1925 to 11,288 in 1926. On this basis, there was one fatality to 1881 producing wells in 1926 as compared with one fatality to 2279 producing wells in 1925.

Only seven of the fatal accidents in the drilling and producing division in 1926 could have been prevented by the installation of safeguards and safety devices as called for in the General Petroleum Industry Safety Orders for Drilling and Production, issued by the Industrial Accident Commission of the State of California. Nearly 50 per cent of the fatalities in 1923, the year previous to the enactment of the safety orders, could have been prevented by the installation of safeguards. The value of safeguards can not be underestimated. No one knows how many fatal accidents are being prevented each year by these all important safety devices. However, no large decrease in numbers of accidents can be expected after operators have made working places safe, unless all employees exercise care for their self protection.

The fatalities listed in the following review are not peculiar to the petroleum industry in California. They are typical of the accidents occurring wherever oil is sought and produced under conditions similar to those in California.

Review of Fatalities in Drilling and Producing Division

Machinery at drilling and producing wells.

a. Rotary drilling engine - chains and sprockets.

1. Driller endeavored to crawl through the engine drive chain in the rear of the draw works. Steam had accumulated in the engine cylinders and when the driller accidentally touched the chain as he was crawling through it, the engine turned over. He was carried by the chain into the engine sprocket and badly crushed.

Every driller should know that it is hazardous to crawl through sprocket chains. Operators realize that it is impossible to guard against all occasional thoughtless acts of employees, so many of them equip the steam cylinder of drilling engines with bleeder valves. These valves are required by law in California. Automatic bleeder valves are installed on drilling engines by many operators in order to still further reduce the possibility of accidents which often occur when accumulated steam within the cylinders of engines, turns the engines over. The operation of such valves is independent of the men and they are of especial value because the men will often forget or deliberately omit opening manually operated bleeder valves before commencing work about engines, sprockets and chains One type of automatic bleeder valve for drilling engines is shown and described in a previous paper by the writer.[6]

b. Calf wheel - chains and sprockets.

1. Head well puller killed when chain flew off the calf-wheel sprocket and struck him on the head.

"Every calf-wheel sprocket shall be provided with a suitable guard to prevent a breaking chain from flying into the derrick."[7] The best calf-wheel sprocket guards enclose the derrick half of the sprocket and are made of flat steel or 6-1/4" casing cut in two longitudinally. Side plates, about 6" wide should be welded to the outer or headache post side of the guard to prevent a broken chain from jumping sideways and injuring the driller or other members of the well crew. The clearance between the top of the sprocket teeth and the inside of the guard should be just enough, about 2-1/2 inches, to allow a chain to jump a sprocket without wrecking the guard. Too much clearance will allow a breaking chain to jump out between the guard and the calf wheel and possibly injure the man at the calf-wheel brake. Calf-wheel sprocket guards should be securely fastened to the head board and the floor. The floor fastening should be

---

6 - Miller, H. C., Mechanical safeguards in rotary drilling: Tech. Paper 369, Bureau of Mines, 1925, p. 34.

7 - General Petroleum Industry Safety Orders, 1924. Order No. 1620, p. 13.

a hinge so that the guard can be lowered when necessary to repair or install a chain on the sprocket. Calf-wheel chain and sprocket guards have been described in detail in a Bureau of Mines publication.[8]

c. Bull wheel - pegs.

1. Roustabout at a well attempted to throw a bull rope off the tug pulley with a steel bar. When the rope came off, he lost his balance and fell against the pins on the side of the bull wheel. Chest crushed and thigh fractured.

Bull ropes in motion should not be thrown off the tug pulley of bull wheels with an iron bar, piece of pipe or stick of wood. Resorting to such practice has resulted in many accidents and occasionally a fatality. Every derrick having bull wheels should be equipped with a bull rope throw-off by means of which the bull rope can be thrown easily from the tug pulley without endangering any one on the derrick floor. The subject of bull rope throw-offs has been dealt with in a previous publication by the writer.[9]

d. Standard engine.

1. Pumper wearing a long slicker was oiling the pumping machinery while same was in motion. From evidence presented after the accident, the slicker caught on an exposed set screw in a collar on the jack shaft.
2. Driller slipped and his leg went into the fly-wheel of the engine. Died as a result of shock following operation for open reduction of femur which was fractured.

Usually, the pumping machinery at oil wells can be stopped for oiling. When conditions in the well are such that it would be detrimental to the well to stop the pumping machinery for a few minutes once a day, other provisions for oiling the moving parts should be made. Oil and grease cups should be located on the outside of the engine guards and connected with the oil ports to the moving parts by metal pipes or tubing. All moving parts of pumping engines should be guarded. Many operators install railings to guard jack shafts, counter-shafts, and band wheel belts so workmen can not come in contact with such machinery and moving parts unless they climb over the railing or enter the enclosure through a gate. Workmen will have no occasion to enter this enclosure while the machinery is in motion when extended grease and oil cups make it possible to lubricate the moving parts from points of safety outside the railing guard. Set screws in shaft collars, exposed key seats, and keys in jack shafts should be guarded as an added precaution, even though the pumping hook-up is enclosed within a railing guard. Workmen should also be cautioned not to wear long slickers, guantlet gloves and loose clothing when working around moving machinery.

---

8 - Miller, H. C., Safeguarding workmen at oil derricks: Bull. 272, Bureau of Mines, 1927, p. 79.

9 - Miller, H. C., Bulletin 272, p. 74.

Unguarded engine flywheels were one of the earliest recognized dangers about steam and internal combustion engines and the oldest safety codes, not only in California but elsewhere, call for the guarding of engine flywheels. It is a simple and easy matter to guard engine flywheels at oil wells and every oil-field worker should know how it should be done and should be capable of building adequate guards when no other means of obtaining them is available. For this reason there is little excuse for an accident due to an unguarded flywheel.

e. Gas engines - clutch.

1. Deceased was a truck driver. While driving a truck past a well he noticed that the beam wasn't oscillating. He had just moved the well gang from this well to another well in his truck, so knew that the beam should have been working. He found that the engine clutch had slipped out, and so attempted to pull the clutch lever over to engage the clutch. A projecting bolt on the band wheel caught the clutch and threw the lever back, catching him in the abdomen and rupturing his liver.

This fatality brings up a question that is heard very frequently in the oil fields. Should a workman attempt to do that work which has been assigned to others even in an emergency. The writer believes that only when life or property is endangered should a workman step in and do work which by virtue of his occupation does not come under his line of duties. This truck driver was undoubtedly acquainted with pumping machinery and believed that all that was necessary to again start the well pumping was to re-engage the clutch. Ordinarily he would have had the well in operation again in a few minutes, perhaps much sooner than if he had gone after a member of the regular crew to do it. However, since no life or property was at stake, it would have been better to have gotten the proper man to do the work. This man would no doubt have known about the projecting bolt in the side of the band wheel and could have started the well without suffering an injury. The projecting end of the bolt in the band wheel should have been removed when the bolt was put in place.

f. Beam hangers, adjusters - hit by falling.

1. Well puller killed when beam hanger fell and crushed his back.
2. Lease foreman and well crew were engaged in pulling a rod into the derrick from the derrick walk. Witnesses believe that the rod hook caught on the adjuster tearing it loose from the end of the walking beam. Adjuster struck the floor and bounded back, striking the foreman who was working the engine control lever on the headache post.

Beam hangers, adjuster cross bars, temper screws and other equipment that must be raised in the derrick to install, should be tied to the catline or otherwise secured while being placed in position. Fewer accidents will occur when such equipment is held suspended in the derrick by the catline until securely fastened in place. Workmen on the derrick floor should also be cautioned not to walk or work unnecessarily underneath such equipment while it is being hoisted, installed or lowered in the derrick.

Adjusters should be clamped securely in the grooves provided for the adjuster T bars in the upper edges of walking beams. For this purpose, adjuster boards 12 inches wide, about 18 inches long and not less than 2 inches thick should be used. These boards, one end of which rests on top of the adjuster T bars should be bolted to the walking beams by bolts 3/4 inch or more in diameter with large cast-iron washers at either end. No adjuster which is suspended from well-fitted grooves in the walking beam and properly clamped down can become dislodged and fall.

g. Elevators - struck by falling elevator link.

1. Rotary helper killed when elevator link became unhooked from casing hook and struck him on the head. Link slipped out of hook when a joint of pipe which had not been securely fastened to the next joint below broke loose when pull was taken on the stand.
2. Driller was standing at the throttle near the calf-wheel jack post raising 3100 feet of 11-1/2" casing which was hanging from a swinging spider. Pull had been taken on the casing and one of the slips removed, when one of the lugs on the spider broke. This allowed one of the links to fall on his head, fracturing his skull.

Open casing hooks or faulty latches have frequently allowed elevator links to fall when stands of pipe "hang up" as they are being lowered or when pipe parts under tension and the recoil causes it to spring upward. At many wells, casing hooks with safety latches that close automatically are being used. Care should be taken to choose a positive type of latch. Such safety latches can be purchased and fitted to almost every make of casing hook. Some operators tie the elevator links to the casing hook by means of a chain or wire cable. This method is also effective, though care must be taken that the chain or cable is not damaged by crushing between the elevator links and the casing hook. Latches or other devices to prevent accidental disengaging of elevator links from casing hooks are required by law in California.

Accidents such as caused the death of the driller when one of the lugs of a swinging spider failed, can be prevented only by using equipment that is strong enough for the work at hand. Swinging spiders ordinarily will carry loads far greater than that of 3100 feet of 11-1/2 inch casing unless defective material has been used in their manufacture. Every precaution should be taken to use only the best materials and workmanship in the construction of oil-well machinery and tools. Swinging spiders, elevators, casing hooks and traveling block beckets should be subjected to a rigid examination for defects in material and manufacture and tested for tensile strength before they are placed on the market. Every manufacturer should realize that a share of the responsibility for preventing accidents falls on his shoulders.

h. Breaking of lines - ton line.

1. Rotary helper killed when tongline broke while breaking out casing. Tong handle struck him over left shoulder.

There are many accidents every year that are caused by the breaking of tong lines. Manila snubbing lines often break when making up or breaking down lengths of drill pipe and casing. When snubbing ropes break under tension, the lead tongs unless equipped with a safety cable usually spin around. If rotary helpers are close enough the handle will strike them. Back-up tongs should also have safety cables to prevent them from turning with the drill pipe or casing. Safety cables should be wire rope, 5/8 to 3/4 inches in diameter, in good condition and securely fastened to the handles of the tongs and snubbed to solid posts.

i. Rotary hose.

1. Picking up kelly from its position in the derrick corner, preparatory to screwing it onto the drill pipe in the hole. When bottom end of kelly was about 2 feet above the floor, the goose-neck on the swivel end of the rotary hose broke. Loose end of hose fell on a rotary helper and fractured his skull.

Though goose-necks on the swivel end of rotary hoses often break while mud fluid is being circulated in a well, they seldom fail when the kelly is not in use or is being made ready to use. Undoubtedly the breaking of the goose-neck was due to its being cracked or to straining almost to the breaking point in previous drilling. The California law[10] states that the swivel end of the rotary hose should be fastened to the goose-neck or to the swivel bail, with a chain or a wire cable. In this case, a fatality would no doubt have been averted had the end of the hose been fastened to the swivel bail or to the swivel itself instead of to the goose-neck. Usually a 3/4-inch chain is used to fasten the hose to the rotary swivel. One end of the chain is clamped to the rotary hose about a foot from the end of the hose, and the other end of the chain is looped around the swivel. This method prevents the end of the hose from falling when the goose-neck fails or the coupling breaks or the threads are stripped when pressure is built up within the hose.

---

[10] - General Petroleum Industry Safety Orders, Order No. 1625e.

j. Miscellaneous.

1. Derrickman killed while rigging up rotary. Crew was hoisting the rotary line shaft into position on the jack posts when a 1-1/2" manila line parted and allowed a traveling block becket which was being used as a counterweight to fall on his head.

Workmen at oil derricks sometimes rig up peculiar makeshifts to do the work at hand and often they do not realize the dangers involved. The crew at this well desired to raise the rotary line-shaft into its bearings on the jack posts. A sling was made of 1-1/2 inch manila rope by fastening the ends to either end of the line shaft. To this sling, one end of a short section of 1-1/2 inch manila rope was tied, the other end being tied to a wire loop in the end of the steel hoisting line. The hoisting line was rigged over the crown block and wound on the calf-wheel shaft. A traveling block becket was tied to this wire loop to act as a counterweight for the hoisting cable. As pull was taken on the hoisting line the manila rope between the wire loop and the rope sling on the line shaft broke. This caused a jerk in the hoisting line which broke the rope that held the becket. The becket fell a distance of about 40 feet, striking and killing the derrickman who was working on the derrick floor. The becket should have been fastened to the steel line directly, instead of being tied to it by a manila rope.

What is needed more than any other one thing to reduce avoidable accidents that are contingent upon incorrect procedure, is to get men to realize the risk of employing makeshift methods. The need for quickly grasping the consequences of failure before haphazard ways are used is also very necessary. On drilling rigs, often too much reliance, as regards strength and safety is placed on manila ropes when more suitable steel lines are available.

Persistent education of the men along general lines of safety, and more rigid requirements for the understanding of fundamental safety rules by the foremen in charge of drilling operations is an objective toward which oil companies engaged in safety work are striving. While progress is slow and results are sometimes discouraging, persistent effort will do much toward decreasing accidents caused by lack of knowledge of safe procedure.

Heavy lifting and straining.

1. Oil worker developed hernia due to severe straining and lifting. Gangrene set in after the operation and he died.

As to hernia cases, the writer can but repeat the paragraph relating to this subject from his report on the 1925 fatalities in the California petroleum industry.[11] "Lifting heavy objects improperly, is always attended by the possibility of strains, sprains and hernia. Employees should be shown the proper way to lift objects. The National Safety Council on Poster No. 1082-B shows the improper and proper way to lift heavy objects. The right way, so the poster reads, is to 'push the entire body upward with the legs.' To do this the back should be straight, the legs bent and the feet directly under the shoulders. The object to be lifted should be as nearly in line with the feet as possible. When lifting with the body in this position the powerful muscles of the legs are brought into play and the load is not thrown on the weaker muscles of the body."

---

[11] - Miller, H. C., Fatalities in the California petroleum industry during the calendar year 1925: Bureau of Mines, Serial 2772, Sept., 1926.

Stepping on objects - nails.

1. Roustabout ran a nail into his foot. Did not stop work when injury occurred. Tetanus set in and he died seven days later.

Stepping on a nail is usually not a serious injury if proper first-aid treatment is applied immediately to prevent infection. Any puncture of the skin should be thoroughly treated with a good antiseptic solution such as iodine or mercurochrome and then covered or protected by a bandage compress to keep out dirt and other foreign substances. Workmen should make use of the first-aid equipment that is provided for them and thereby save themselves much suffering and often death. In almost every injury it is advisable to consult a physician as soon as possible after the first-aid treatment.

Struck by moving object - pipe.

1. Rotary helper was helping to load drill pipe upon a truck from the casing rack. A rope was being used to pull the pipe up the incline. This rope became loose and allowed the pipe to roll down the skids, and the rotary helper was crushed between the rolling pipe and the pipe in the rack.

Regardless of the method used to roll pipe upon a truck or from a truck to a rack, workmen should not stand between the skids below the pipe. One can never tell when something may happen that will allow the pipe to run back. This should be made a hard and fast rule by every company because many accidents occur every year when workmen get caught between pipe while loading or unloading it from trucks.

Struck by falling objects - from derrick.

1. Well puller killed when top of derrick was pulled in while tubing was being pulled.
2. Rotary helper killed when struck by falling board which had been loosened when the top of the derrick was broken. Crew was attempting to loosen a stand of drill pipe.
3. Tool dresser killed when crown block was pulled in while pulling casing. Skull fractured.

When derrick foundation piers settle unevenly, the crown of the derrick is thrown out of line with the hole being drilled. When the derrick is considerably out of plumb, the load is unevenly distributed on the four derrick legs. Such a derrick will not stand the same pull as one that is plumb and there is danger of pulling in the derrick when a load is applied. Derrick legs that have settled should be jacked up and shimmed before drilling is continued. Wooden derricks deteriorate rapidly with age and are not as strong after standing for several years exposed to the weather as they were when first constructed. Redrilling or deepening jobs sometimes require derricks to be as strong or stronger than they were at the time they were built. If the nails in the derrick members have become loosened through alternate swelling and shrinkage of the lumber due to climatic changes, they should be redriven and the derrick members renailed where necessary. Often it is necessary to add an entire set of new braces in order to bring the derrick up to the required strength.

Although slight misalignment of the crown sheaves can be corrected by shifting the sheaves and the I-beams, large corrections in alignment should not be made in this manner. Crown block I-beams should at all times have a full bearing on the bumper timbers. With anything less than a full bearing there is danger of pulling in the crown blocks and injuring or killing some member of the crew on the derrick floor.

Falls of persons - from derricks.

1. Derrickman was climbing up the inside of the derrick, pulling after him a section of cable, attached to a manila rope, which was looped over his shoulder. When 35 feet up in the derrick, the wire cable whipped around a chain and jerked him loose. He fell to the derrick floor, fracturing his right leg.
2. Rig builder lost his footing while up in the derrick, and fell.

How much safer it would have been to have hoisted the cable up the derrick by means of the cat line. The derrickman could then have climbed up the derrick ladder, put on his safety belt with the life line securely tied to a derrick girt or brace, and then carried on his work without danger of falling.

Rig drilling is dangerous work and safety principles should be thoroughly embedded in every rig builder's mind. Only men who are accustomed to working at heights above the ground and who have been found, through medical examination, to be physically fit for such work, should follow the rig-building trade.

Automobiles.

1. Roustabout killed in an automobile collision.

The introduction of the automobile and truck into the business and pleasure activities of the nation, has brought the American people face to face with the problem of preventing annually the destruction of over 20,000 lives. The petroleum industry realizes that this sacrifice of human beings is unnecessary and has for many years been one of the leaders in the highway safety movement. Its cooperation with city, county, and state officials has done much to hold down the annual rate of increase of accidents caused by automobiles and trucks. No company, group of citizens, highway safety associations, or corps of traffic officers, however, can be instrumental in reducing the number of accidents appreciably unless drivers of motor vehicles cooperate with them in their endeavor to make travel on roads, streets, and highways safe. There will be fewer accidents when every driver of a motor vehicle realizes and puts into practice such rules as safe driving warrants.

Burns.

a. Electricity.

1. Rig fireman entered a boiler to clean it, taking with him an electric lamp attached to an extension cord carrying 110 volts. He was apparently electrocuted when found.

b. Powder burns.

1. Roustabout was blasting site for pipe-rack foundation. In lighting a fuse some powder that he had spilled ignited. He started to run, picking up a small can of powder which had been standing near. This powder ignited as he picked it up and set fire to his clothing.

No man should enter a boiler unless another man is stationed outside at the manhole to render aid if necessary. Many things can happen to the man working inside the boiler that might render him unconscious and result in death unless rescued from the boiler immediately. He might faint due to the heated and stuffy atmosphere within the boiler, or he might be rendered unconscious by a blow on the head or from electric shock. Many companies forbid employees to use electric extension cords and lamps when working inside of boilers. Extension cords and connections are seldom in perfect condition electrically, and since boiler shells usually afford an excellent ground for electric currents there is always danger of a short circuit between the electric equipment and the boiler. The use of pocket flashlights is recommended.

Only men who are experienced in handling explosives should be allowed to use them. Blasting powder is not dangerous when handled properly. The roustabout should not have tried to light the fuse until he had disposed of the powder that he spilled in filling the hole. No experienced powder man would have tarried long enough under the circumstances to pick up an unignited can of powder.

Miscellaneous.

a. Gassed and drowned.

1. Driller climbed into an oil tank to gage the oil. He was overcome by fumes and fell into the oil, which was only a few inches deep, and was drowned.

It is dangerous for a man to enter an oil-storage tank unless equipped with "suitable breathing apparatus," with a rope made fast to his body, and attended by a man on the outside of the tank. Types of breathing apparatus recommended by the U. S. Bureau of Mines for use in entering oil storage tanks and containers, and their uses and limitations, are described in Technical Paper 348.[12] Because Order No. 1630 of the General Petroleum Industry Safety Orders of California covers this case so thoroughly, it is reprinted herewith in full.

> "Order 1630. Oil and Gas Storage Tanks and Containers.
>
> (a) No workman shall be required to enter any tank or other container used for the storage of crude oil, or any product thereof, or any confined space until it has been freed from injurious gas, unless he is equipped with suitable breathing apparatus and appurtenances.
>
> (b) No workman shall be required to enter any tank or other container provided only with manholes in the top, excepting earthen and concrete lined reservoirs, until he has been supplied with a rope which shall be made fast to his body and to a substantial support on the outside of the tank or other container. The rope must be of sufficient length to reach from the outside support to any point of work in the tank or container, and shall be of sufficient strength to bear the weight of the workman.
>
> (c) No workman shall be required to enter any tank or other container provided only with manholes in the tops, unless attended by a man whose duty it is to stay on the outside of the tank or container and to keep close watch over the men in the tank or other container.
>
> (d) All work in any confined space when atmospheric conditions are nauseating, or in any way cause indisposition on the part of the workmen, shall be arranged in short shifts, the men on the outside alternating to relieve those inside."

FATALITIES IN THE PIPE-LINE AND TRANSPORTATION DIVISION.

For the first time since 1920, which is as far back as records are available, the pipe-line and transportation division of the California petroleum industry had more than four fatalities in any one year. Of the 10 fatal injuries occurring in this division in 1926, two were highway accidents in which two men were killed when their car left the road on a mountain grade. These two fatalities are classified as industrial because the men were going from one job to another. The pipe-line and transportation division is being charged with these two fatal accidents because the men were to do work in that division.

Review of the Fatalities in the Pipe Line and Transportation Division.

Burns. - Petroleum products.

1. Four men killed. Crew was preparing to weld a 4-inch line to a 6-inch line underneath a dock and near the surface of the water. The 6-inch line was 1200 feet

---

[12] - Katz, S. H. and Bloomfield, J. J. Gas masks for gasoline and petroleum vapors, Tech. Paper 389, Bureau of Mines, 1924, 37 pp.

long, the farther end being connected to a storage tank. The 6-inch line had been pumped dry and blown out with air under 50-pound pressure for 30 minutes. It was then filled with water. When the blind flange was removed from the 6-inch line some gasoline ran out with the water, showing that the line had not been thoroughly drained of gasoline. Sparks from the welding torch ignited the gasoline that floated on the water below the line and this in turn ignited gasoline vapors in the line and an explosion followed.

This accident shows that blowing air under 50-pound pressure for 30 minutes does not free a 6-inch gasoline line, previously pumped dry, of gasoline that had accumulated in low spots along the line. However, from the reports of the accident it appears that it was the gasoline that had accumulated on the surface of the water under the line that ignited first and was the primary cause of the explosion. In doing work of this nature, too little attention is given usually to freeing pipe lines of combustible vapors. Pipe lines should be blown out with air and preferably with steam for at least 2 or 3 hours and often longer. If the line is then filled with water and gasoline colors are noted on the water as it is being drained, the steaming process should be repeated. Before welding is finally started, every precaution should be taken to dispose of pools of accumulated gasoline or gasoline and water, so that sparks from the welding torch and vapors from the gasoline will not come together and cause an explosion.

Struck by falling objects.

1. While raising a gin pole to unload tank steel from a railroad car, a foreman lost his footing and fell with the pole to the ground. Head crushed.

Many accidents are caused by falling gin poles, usually because of improper guying or poor supports. Plenty of men should be used when raising a gin pole in order to prevent the pole from overbalancing or toppling over sideways. Workmen should be cautioned also to stand back out of the danger zone so as to be in the clear, if the pole should accidentally fall.

Automobiles.

1. Automobile accident on mountain grade. Two men killed. The exact cause of the car leaving the highway is not known.

Ditch cave-in.

1. Pipe liner killed when ditch caved in. Trench was being dug about 7'8" deep and 2 feet away from and parallel to another ditch that had been previously dug and only recently filled in. This weakened the two-foot strip between trenches and caused it to cave.

Trenches being dug in loose ground or when carried to depths exceeding five feet should be shored and sheeted to prevent the sides from caving.

Miscellaneous - drowned.

1. Two men killed. Water draw-off pipe underneath an 80,000-barrel oil-storage tank developed a leak at the elbow. A repair crew made an excavation underneath the edge of the tank large enough to expose the draw-off pipe. While they were attempting to screw on a new elbow, the pressure of the oil forced a sack of earth, which had been placed inside the tank over the drain outlet, through the drain-off nipple. This 6-inch stream of oil ran unchecked until a heavier plug was landed over the hole. The workmen then constructed a small coffer-dam around the excavation and bailed it dry. Meanwhile, the station pumps were pumping oil out of the tank. The tank bottom failed without warning, and a wave of oil engulfed the workers. Those who escaped, swam to safety. No men were underneath the tank when it failed. Inspection after the basin was drained showed that the bottom sheet next to the one containing the draw-off flange had failed at the seam opposite the bottom angle and at right angles to the radius of the tank. This sheet was then torn loose from the two adjoining and was held only by the rivets to the bottom angle. The sheet containing the draw-off flange failed next in exactly the same manner and also was held to the tank only by the rivets to the bottom angle. It seems probable that the oil from the 6-inch stream saturated the earth under a considerable area of the tank bottom and also washed out a large volume of earth. This undoubtedly allowed the two bottom sheets to sag and later fall.

No attempt to repair leaks in the bottoms of tanks containing oil, other than to temporarily stop the leaks by plugging with earth or sand bags should be made until the oil has been drained out of the tank. Sand bags, lowered through the oil from an opening in the tank roof directly above the leak, and placed over the leak will usually accomplish this without endangering life. Care must be taken, however, when cutting out a section of the steel roof that no sparks are formed to ignite the oil in the tank or the gas above the oil. On this job, a water spray was used to prevent sparks. No excavation should be made underneath a tank and no attempt should be made to repair a leak in a tank bottom until the tank is empty. Every precaution should also be taken with near-by fires so that no fire hazard exists in case a tank should fail before all the oil is pumped out.

FATALITIES IN THE REFINERY DIVISION.

The fatalities in the refinery division of the California petroleum industry in 1926 again show that the hazard about gasoline plants is greater than at plants where crude oil is refined. There were no fatalities at refineries that were pertinent to the actual refining of oil. The fatalities that did occur about refineries were incidental to the actual refining of oil and were accidents that might have occurred in the oil fields or along the pipe lines. This is a record unequalled perhaps anywhere in any other industry, especially when consideration is given to the character of the products handled and to the large number of men employed.

Review of the Fatalities in the Refinery Division

Burns. - Saturated by products.

1. Six men killed. Gasoline was being pumped through a 4-inch line into a tank 7 feet in diameter and 20 feet high. Tank had two 2-inch safety valves set at 30-pound pressure. The shell of the tank was riveted and the heads were welded. The upper head failed in the weld and was thrown about 100 feet. Gasoline vapors rose from the tank and about 10 seconds later a flash occurred. It is presumed that the vapors traveled to a rig boiler about a hundred feet distant and ignited.

This disaster was the most serious in point of number of men killed, that has occurred about gasoline plants in California. Engineers from the Industrial Accident Commission hold the opinion that the accident was caused by the top head of the storage tank failing in the weld. This head was a bumped disc 5/16" thick, was not flanged, and was welded to a 3/16" shell plate. This design placed the weld at the point of maximum stresses occasioned by internal pressure, and bending action due to "breathing" of the tank. Especially for tanks containing inflammable materials, the Commission's Engineers recommend flanged heads, either riveted, lap welded, or butt welded to the shell. There were no indications after the accident to show that the safety valves were stuck or failed to function, so it is reasonable to assume that the pressure within the tank had not risen to 30 pounds. In order to provide for a possible hydrostatic pressure due to "overpumping" it would be a wise provision to make the safety valves and fittings of sufficient capacity to relieve fully the liquid output of the supply line to the tank.

This accident brings up again the question of the proper location of boilers, heaters and other open flames with respect to gasoline plants. In this connection it may be mentioned that at every one of California's serious gasoline and refinery plant fires in the past years, fired boilers have been less than 100 feet from the source of the gasoline vapors. The distance that boilers should be from a gasoline plant depends on the direction of the prevailing winds and the topography of the area around the plant. It is reasonable to suppose, however, that if boilers and other open flames were located 300 or more feet from gasoline plants and gasoline storage, or substantial barricades constructed between them, so designed as to divert streams of inflammable gas, workmen would have a better chance to escape in time of disaster.

Struck by falling object.

1. Carpenter's helper was helping to erect an A-derrick on top of a tank. He stood between the derrick and the edge of the tank. Derrick fell over and knocked him to the ground, fracturing his spine.
2. Pipe-fitter's helper was digging a ditch into which pipe was being lowered by means of a tripod. The pipe fell, crushing his skull and fracturing his spine.

The A-derrick would not have fallen if it had been properly secured at its base. Working on tank roofs and especially near the edge of the roofs is hazardous. Accidents from men falling from tank roofs might be prevented by compelling workmen to wear life belts. If a metal eye bolt were riveted or welded to the tank roof at its center, to which a life line from the safety belt could be tied and this life line just long enough to reach to the edge of the tank, such accidents might be prevented.

Workmen in ditches or on the ground should never risk their lives under material that is being raised or lowered above their heads. No mechanical equipment is foolproof, and the many men that have been killed when suspended material was dropped is proof enough that standing clear of such material is the best practice.

Miscellaneous.

a. Gassed.

1. Car loader's body found inside of empty gasoline tank car. He was probably overcome by gasoline fumes.

b. Explosion.

1. Gager was gaging distillate in a storage tank. Tank exploded. Cause unknown.

c. Automobile.

1. Boiler-maker's helper was run over by a truck belonging to a trucking company while truck was making a delivery in the refinery yard.

Every workman should know that it is dangerous to enter a tank or any vessel used for storing or transporting gasoline unless equipped with suitable breathing apparatus[13] and attended by a man on the outside to give aid if necessary. In California it is illegal to require a man to enter a tank except under certain conditions. See General Petroleum Industry Safety Order No. 1630 given in full on page 14 of this paper.

---

[13] For tests of hose masks, gas masks and oxygen breathing apparatus, and recommendations, see Technical Paper 348, "Gas masks for gasoline and petroleum vapors," by S. H. Katz and J. J. Bloomfield, 1924, 37 pp.

FATALITIES IN THE SALES AND MARKETING DIVISION

Four of the five fatalities that occurred in the sales division of the California petroleum industry in 1926 were automobile accidents. Accidents to automobile and truck drivers and the prevention of such accidents are the biggest problems facing the sales division in their work of preventing accidents. Generally speaking, company sales departments have attacked the problem vigorously and their drivers as a rule are much more careful than the ordinary driver of a motor vehicle. Especially is this true of the drivers of the larger companies' tank trucks. Only one driver of a tank truck was killed in 1926, and there were no grade-crossing fatalities to petroleum company employees driving company vehicles.

Review of Fatalities in the Sales and Marketing Division.

Automobile.

1. Collector's car was struck by another machine and he was thrown out of his car. Skull fractured.
2. Salesman was driving a company car at 35 miles per hour. When passing a blind road a car came out on to the highway. The salesman tried to avoid hitting the car, his car swerved, ran into a ditch, turned over and broke his neck.
3. Tire blew out, car turned over, chest crushed. Salesman.
4. Truck driver. Truck skidded and struck curb.

Automobiles and trucks are becoming more and more the modern means of transportation in the oil industry, and petroleum companies generally have taken an active part in seeking to reduce the appalling loss of life, suffering and damage to property which result from automobile accidents. Oil companies however can not prevent those accidents which are due to "the other fellow's" carelessness. No material reduction of the number of fatalities due to automobile accidents can be expected until every driver of a motor vehicle realizes that safe driving, obeying traffic regulations and road courtesy are the law of the land and then puts this knowledge into practice.

Burns - saturated by products.

1. Tank-truck salesman was servicing a tractor when tractor driver spilled gasoline on the hot exhaust pipe. A flash ignited the fill box. Tractor driver pulled the fill box from the tank and threw it on the ground. This ignited the 5-gallon can of gasoline which the truck salesman had in his hands ready to hand to the tractor driver. This in turn set his clothes on fire.

Such an accident exemplifies again the hazards of allowing gasoline to overflow and drip on a hot exhaust pipe. Accidents of a similar nature are frequent at service stations, though it is believed to a lesser degree than a few years ago. Service station attendants have learned to be careful and not to spill gasoline when servicing automobiles and trucks or to let the tanks run over. Accidents of this kind might be eliminated if automobile and truck manufacturers changed the design of motor vehicles so that exhaust pipes would not be directly below the inlet openings in gasoline tanks.

ACKNOWLEDGMENTS

The number and causes of the fatalities reviewed were taken from the files of the statistical department of the Industrial Accident Commission of the State of California; and helpful assistance in making the accident reports available was rendered by C. R. MacDonald and F. B. Lord of that department. Valuable criticisms and comments were made by Charles M. Butler, manager, personnel department, General Petroleum Corporation of California; George F. Prussing, secretary, safety board, and Hugh A. Matier, safety engineer, Union Oil Company of California; E. G. Sheibley, superintendent and chief engineer, T. W. Osgood, assistant superintendent, J. Wesley Gebb and G. Chester Brown, engineers, safety department, Industrial Accident Commission of the State of California; Arthur Johnson, safety engineer, producing department, Standard Oil Company of California; and H. H. Hill, H. C. Fowler, C. P. Bowie and G. B. Shea of the Bureau of Mines. - Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un32mo
cop.2

Serial No. 2815.
June, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE--BUREAU OF MINES

THE LIBRARY OF THE
JUL 23 195
UNIVERSITY OF ILLINOIS

COAL-MINE FATALITIES IN MAY, 1927

By W. W. Adams[1]

Accidents in the coal-mining industry of the United States in May, 1927, caused the death of 178 men, according to information furnished by State mine inspectors to the federal Bureau of Mines, Department of Commerce. Of this number 127 deaths occurred in bituminous mines and 51 in anthracite mines. The death rate per million tons of coal mined during the month was 4.10, based on a production of 43,395,000 tons, as compared with 3.80 for May, 1926, based on an output of 47,113,000 tons. The rate for bituminous coal alone, for May, 1927, was 3.59 with a production of 35,393,000 tons, and that for anthracite was 6.37 with a tonnage of 8,002,000, as compared with 3.38 and 5.84, respectively, for May of last year, based on a production of 39,059,000 tons and 132 deaths, and 8,054,000 tons and 47 deaths.

During the first five months of 1927, accidents at coal mines caused the loss of 999 lives. The production of coal during this period was 273,644,000 tons, showing a death rate of 3.65 as against 4.03 for the same five months in 1926, based on 1,020 deaths and a production of 252,831,000 tons. The record for bituminous mines alone from January to May, 1927, was 783 fatalities and 240,000,000 tons with a fatality rate of 3.26, while that for anthracite showed 216 deaths, 33,644,000 tons and a death rate of 6.42. The same period for 1926 showed 888 deaths and 225,514,000 tons with a rate per million tons of 3.94 for bituminous; and 132 deaths, 27,317,000 tons and a rate of 4.83 for anthracite.

Three major disasters, that is, accidents causing the loss of five or more lives, occurred during the month of May. All of these disasters were explosions. One at Capels, West Virginia, on May 13, killed 8 men. On May, 26, 7 men were killed in an anthracite mine at Edwardsville, Pennsylvania, and 7 men lost their lives on May 27, at Delagua, Colorado. These three accidents bring the total number of such disasters to 7 with a resulting loss of 140 lives during the first five months of the present year as compared with 8 for the same period of 1926, with a loss of 194 lives. Fatality rates based exclusively on these figures were 0.512 and 0.767 per million tons for 1927 and 1926, respectively.

Comparing the accident record from January to May of the present year with that for the same period of 1926, a reduction is noted in the death rates per million tons for falls of roof and coal, haulage, and gas or dust explosions; while a slight increase is shown for explosives and electricity.
The comparative rates are as follows:

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

	Year 1926	Jan.-May 1926	Jan.-May 1927
All causes	3.790	4.034	3.651
Falls of roof and coal	1.829	1.891	1.644
Haulage	.650	.669	.603
Gas or dust explosions:			
Local explosions	.111	.119	.~~464~~ .154
Major explosions	.525	.767	.~~154~~ .464
Explosives	.145	.119	.179
Electricity	.143	.107	.150

Table 1 gives comparative figures showing the number of deaths per million tons from each of the principal causes of accidents for the year 1926, and for the first five months of 1926 and 1927, respectively. Table 2 shows the number of fatal accidents in May 1927, classified by causes and States. Table 3 shows the number of fatalities in January, February, March, April, and May, 1927, by States.

Table 4 is a comparative table showing the percentage of fatalities and the number of deaths per million tons of coal produced for each of the principal causes of accidents at bituminous and anthracite mines, separately, for the ten-year period 1917-1926, and for the years 1925 and 1926; it also shows the average May rate over a ten-year period. A similar comparison may also be made with April 1927, with May 1926, and with May 1927.

Table 5 shows the production of coal, number of men employed, number killed, and fatality rates based upon the number of 300-day workers and also upon the tons of coal mined in the United States and several European countries. These figures are shown for the United States as a whole and for bituminous and anthracite mines, separately, and may be compared with similar figures for Great Britain, France, Belgium, and Prussia for the years 1921 to 1925, inclusive, except for France whose latest report available was for 1924. An average for these years is also given.--Reports of Investigations, Department of Commerce, Bureau of Mines.

TABLE 1.- NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES

	Year 1926	Jan.-May 1926	Jan.-May 1927
Falls of Roof & Coal....................	1.829	1.891	1.644
At face..............................	1.386	1.432	1.209
In room..........................	.238	.257	.234
On entry......	.193	.198	.190
On slope.............................	.012	.004	.011
Haulage.................................	.650	.669	.603
Switching and spragging..............	.020	.028	.004
Coupling.............................	.008	.008	.026
Falling from trips...................	.030	.020	.040
Run over.............................	.241	.257	.237
Caught between car and rib...........	.136	.134	.146
Caught between car and roof..........	.027	.028	.033
Runaway cars....	.057	.028	.066
Miscellaneous........................	.131	.166	.051
Gas or Dust Explosions..................	.636	.886	.618
Open light...........................	.191	.071	.091
Defective safety lamp................	.005	- -	- -
Electric arc.........................	.081	.020	.029
Shot.................................	.077	.182	.044
Powder explosion.....................	.005	.012	.004
Miscellaneous........................	.277	.601	.450
Explosives..............................	.145	.119	.179
Transportation.......................	- -	- -	- -
Charging.............................	.006	.016	.007
Suffocation..........................	.008	.008	- -
Drilling into old holes..............	.003	- -	- -
Striking in loose rock...............	- -	- -	- -
Thawing..............................	- -	- -	- -
Caps & detonators....................	.001	.004	.011
Unguarded shots......................	.006	.008	.007
Returned too soon....................	.013	.012	.011
Premature shot.......................	.048	.028	.048
Sparks from lamp, etc................	.005	.008	.011
Delayed shots...............	.015	.004	.018
Shot breaking through rib............	.011	.008	.026
Miscellaneous........................	.029	.023	.040
Electricity.............................	.143	.107	.150
Direct contact with trolley wire......	.050	.032	.051
Tools striking trolley wire..........	.003	.008	.004
Contact with mining machine..........	.013	.004	.015
Contact with machine feed wire........	.009	.012	.022
Contact with haulage motor............	.003	- -	- -
Miscellaneous........................	.065	.051	.058

TABLE 2.- COAL-MINE FATALITIES DURING MAY, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																													
Falls of roof..........	4	--	--	--	2	--	1	--	5	--	--	--	--	1	--	4	--	14	--	--	--	3	5	1	16	--	56	17	73
Falls of side...........	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--	--	3	--	7	4	11
Haulage................	--	--	1	--	--	--	--	--	3	--	--	--	--	--	--	--	--	1	--	--	--	--	4	1	13	--	23	4	27
Gas or dust explosions...	--	--	--	7	--	--	--	--	1	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	8	--	17	9	26
Explosives..............	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	2	11	13
Suffocated by mine gases.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1
Electricity........... .	1	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	6	--	10	1	11
Animals................	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mining machines.........	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	2	--	2
Mine fires..............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other causes............	--	--	--	--	2	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	4	7
TOTAL...............	6	--	1	8	4	--	1	--	11	--	--	--	--	1	--	5	1	19	--	--	--	3	9	2	49	--	120	51	171
SHAFT																													
Persons falling.........	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Objects falling.........	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cages, skips............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other causes............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL.............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SURFACE																													
Mine cars..............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	2	--	2
Electricity.............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Machinery...............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	1	--	1
Boiler explosions........	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Railway cars............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	1	--	1
Other causes............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	1	--	3	--	3
TOTAL.............	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	5	--	7	--	7
GRAND TOTAL, May, 1927...	6	0	1	8	4	0	1	0	11	0	0	0	0	1	0	5	1	21	0	0	0	3	9	2	54	0	127	51	178
GRAND TOTAL, May, 1926...	2	0	0	6	12	1	0	5	15	1	0	0	0	0	0	9	2	27	0	1	0	3	4	0	42	2	132	47	179

TABLE 3.- COAL-MINE FATALITIES DURING 1927, BY MONTHS AND STATES

MONTH	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January..................	6	-	2	8	19	3	1	-	23	-	1	1	1	2	-	7	2	35	-	3	-	1	2	1	42	4	164	44	208
February.................	7	-	2	5	11	6	1	2	10	-	-	-	1	1	2	9	2	30	-	-	-	5	5	2	35	-	136	41	177
March....................	6	-	-	7	23	7	1	2	6	-	-	-	-	2	-	6	2	35	-	3	-	2	3	1	38	1	145	40	185
April....................	6	-	-	2	4	-	2	-	2	-	1	-	1	-	-	3	2	33	-	1	-	3	3	7	[a]141	-	211	40	251
May......................	6	-	1	8	4	-	1	-	11	-	-	-	-	1	-	5	1	21	-	-	-	3	9	2	54	-	127	51	178
TOTAL, 5 Months.......	31	0	5	30	61	16	6	4	52	0	2	1	3	6	2	30	9	154	0	7	0	14	22	13	310	5	783	216	999

a/ Explosion killed 97; 91 underground and 6 on the surface. Figures subject to revision.

TABLE 4.- AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED

Cause of accident	Per cent of total, 1917-1926	Death rates per million short tons						
		Average for 10 years 1917-1926	Year 1925	Year 1926	Average for May 10 years 1917-1926	1927		1926
						Apr.	May	May
		Bituminous Mines						
1. Falls of roof and coal	48.96	1.759	1.750	1.717	1.668	1.442	1.780	2.048
2. Underground haulage	18.18	.653	.586	.655	.683	.663	.650	.742
3. Explosions of gas or coal dust:								
Local explosions	2.91	.104	.112	.080	.093	.058	.057	.154
Major explosions	10.84	.390	.469	.565	.221	2.797	.424	- -
4. Explosives	3.30	.118	.094	.080	.107	.173	.057	.077
5. Electricity	4.01	.144	.154	.161	.146	.115	.282	.051
6. Mining machines	1.33	.048	.067	.045	.062	.087	.057	.077
7. Other causes underground	2.93	.105	.089	.067	.122	.346	.084	.102
8. All causes underground	92.46	3.321	3.321	3.370	3.102	5.681	3.391	3.251
9. All shaft accidents	1.73	.062	.058	.047	.026	.058	- -	- -
10. All accidents on surface	5.81	.209	.148	.147	.208	.346	.197	.128
11. All accidents	100.00	3.592	3.527	3.564	3.336	6.085	3.588	3.379
		Anthracite Mines						
1. Falls of roof and coal	42.71	2.496	2.750	2.588	2.477	2.664	2.624	2.359
2. Underground haulage	12.75	.745	.906	.612	.670	.701	.500	.745
3. Explosions of gas:								
Local explosions	6.71	.392	.421	.329	.424	1.122	.250	.869
Major explosions	1.51	.088	.275	.247	.164	- -	.875	.621
4. Explosives	12.37	.723	.857	.588	.479	.841	1.374	.372
5. Electricity	1.00	.059	.065	.024	.027	- -	.125	- -
6. Other causes underground	8.18	.478	.323	.459	.712	.281	.625	.745
7. All causes underground	85.23	4.981	5.597	4.847	4.953	5.609	6.373	5.711
8. All shaft accidents	2.30	.134	.065	.094	.219	- -	- -	.124
9. All accidents on surface	12.47	.729	.809	.388	.465	- -	- -	- -
10. All accidents	100.00	5.844	6.471	5.329	5.637	5.609	6.373	5.835

Table 5.- Production, men employed, number killed, and fatality rates for the United States compared with labor data for foreign countries

Country	Production		Men employed			Number killed			Killed per 1,000 300-day workers	Killed per 1,000,000 tons of coal mined
	Tons[1] (usual unit)	Tons (short tons)	Under-ground	Sur-face	Total	Under-ground	Sur-face	Total		
United States (bituminous)										
1921	----	415,921,950	567,289	96,465	663,754	1,365	83	1,448	4.38	3.48
1922	----	422,268,099	582,409	105,549	687,958	1,582	102	1,684	5.16	3.99
1923	----	564,564,662	600,305	104,488	704,793	1,856	97	1,953	4.65	3.46
1924	----	483,686,538	531,904	87,700	619,604	1,822	84	1,906	5.39	3.94
1925	----	520,052,741	506,541	81,952	588,493	1,757	77	1,834	4.79	3.53
Average, 5 years	----	481,298,798	557,690	95,231	652,921	1,676	89	1,765	4.87	3.67
United States (anthracite):										
1921	----	90,473,451	116,817	42,682	159,499	510	37	547	3.80	6.05
1922	----	54,683,022	114,279	42,570	156,849	264	36	300	3.81	5.49
1923	----	93,339,009	114,721	43,022	157,743	448	61	509	3.62	5.45
1924	----	87,926,862	119,363	40,646	160,009	442	54	496	3.39	5.64
1925	----	61,817,149	120,568	39,744	160,312	350	50	400	4.12	6.47
Average, 5 years	----	77,647,899	117,149	41,733	158,882	403	47	450	3.71	5.80
United States Total:										
1921	----	506,395,401	684,106	139,147	823,253	1,875	120	1,995	4.20	3.94
1922	----	476,951,121	696,688	148,119	844,807	1,846	138	1,984	4.90	4.16
1923	----	657,903,671	715,026	147,510	862,536	2,304	158	2,462	4.39	3.74
1924	----	571,613,400	651,267	128,346	779,613	2,264	138	2,402	4.80	4.20
1925	----	581,869,890	627,109	121,696	748,805	2,107	127	2,234	4.65	3.84
Average, 5 years	----	558,946,697	674,839	136,964	811,803	2,079	136	2,215	4.58	3.96

Continued.

Table 5. - Production, men employed, number killed, and fatality rates for the United States compared with labor data for foreign countries (Continued).

Country	Production		Men employed			Number killed			Killed per 1,000 300-day workers	Killed per 1,000,000 tons of coal mined
	Tons 1/ (usual unit)	Tons (Short tons)	Under-ground	Sur-face	Total	Under-ground	Sur-face	Total		
Great Britain:										
1921	168,042,549	188,207,655	918,066	226,245	1,144,311	682	74	756	1.08	4.02
1922	255,971,696	286,688,300	933,029	229,725	1,162,754	999	106	1,105	1.09	3.85
1923	283,958,247	318,033,237	979,785	240,646	1,220,431	1,179	118	1,297	1.15	4.08
1924	275,301,859	308,338,082	979,108	251,140	1,230,248	1,087	114	1,201	1.10	3.90
1925	250,907,326	281,016,205	890,849	226,979	1,117,828	1,028	108	1,136	1.21	4.04
Average, 5 years	246,836,335	276,456,696	940,167	234,947	1,175,114	995	104	1,099	1.13	3.98
France:										
1921	28,960,473	31,923,129	143,025	76,723	219,748	144	61	205	.99	6.42
1922	31,940,845	35,209,496	154,332	75,468	229,800	133	56	189	.87	5.37
1923	38,556,437	42,500,761	183,468	80,527	263,995	186	42	228	.97	5.36
1924	44,981,556	49,583,169	203,444	83,118	286,562	234	47	281	1.03	5.67
Average, 4 years	36,109,828	39,804,139	171,067	78,959	250,026	174	52	226	.97	5.68
Belgium:										
1921	21,750,410	23,975,477	113,191	50,949	164,140	131	15	146	.91	6.09
1922	21,208,500	23,378,130	103,444	49,394	152,838	106	36	142	.91	6.07
1923	22,922,340	25,267,295	109,639	50,364	160,003	151	24	175	1.07	6.93
1924	23,361,910	25,751,833	118,981	53,304	172,285	165	37	202	1.18	7.84
1925	23,097,040	25,459,867	109,916	50,467	160,383	132	15	147	.90	5.77
Average, 5 years	22,468,040	24,766,520	111,034	50,896	161,930	137	25	162	1.00	6.54
Prussia:										
1921	131,628,388	145,093,972	521,354	222,493	743,847	1,254	233	1,487	1.86	10.25
1922	114,898,275	126,652,369	457,081	180,943	638,024	1,107	198	1,305	1.89	10.30
1923	58,351,151	64,320,474	447,060	193,188	640,248	899	126	1,025	1.50	15.94
1924	114,901,305	126,655,709	362,084	131,153	493,237	942	148	1,090	2.12	8.61
1925	128,709,072	141,876,010	362,209	127,254	489,463	1,180	140	1,320	2/	9.30
Average, 5 years	109,697,638	120,919,707	429,958	171,006	600,964	1,076	169	1,245	3/1.86	10.30

1/ Production expressed in long tons for Great Britain and in metric tons for France, Belgium, and Prussia.

2/ Not available.

3/ For a 4 year period

622.09
Un 32 mo
cop. 2

Serial No. 2816
June, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

CONSUMPTION OF EXPLOSIVES IN MAY, 1927.

By W. W. Adams[1]

The quantity of explosives manufactured in the United States and sold in May 1927 for domestic consumption was 345,300 kegs (8,632,500 pounds) of black blasting powder, 5,236,000 pounds of permissibles, and 28,957,000 pounds of high explosives other than permissible. These figures are based on reports received by the Bureau of Mines, Department of Commerce, from nearly all manufacturing companies, and include an estimate of sales by several companies that do not furnish monthly reports. Reports actually received showed sales of 338,433 kegs of black powder, 5,228,124 pounds of permissible explosives, and 27,208,177 pounds of high explosives other than permissible. The sales in May 1927, when compared with May 1926, represent a decrease of 7 per cent for black powder, an increase of 8 per cent for permissibles, and an increase of 2 per cent for other high explosives.

PERMISSIBLE EXPLOSIVES: Sales of permissibles in the first five months of 1927 amounted to 27,295,000 pounds, including 27,254,957 pounds sold by reporting companies and an estimate to cover several companies that do not furnish monthly figures. In comparison with the same months last year, the figures for this year show an increase of 14 per cent. Ninety-six per cent of the permissibles sold thus far in 1927 were for use in coal mining (28 per cent being used by anthracite mines and 68 per cent by bituminous mines). The consumption of permissibles at bituminous coal mines since January 1st has averaged 77 pounds for each thousand tons of coal mined; this amount represented 29 per cent of the 265 pounds of all kinds of explosives consumed per thousand tons of bituminous coal produced. At anthracite mines 229 pounds were used for each thousand tons of anthracite coal produced, which was 31 per cent of the 742 pounds of all kinds of explosives used per thousand tons. During the first five months of 1927, the largest quantities of permissibles were used in the States of Pennsylvania, West Virginia, Alabama, and Kentucky.

BLACK BLASTING POWDER: The amount of black blasting powder sold during the first five months of the present year was 2,216,200 kegs, including 2,171,952 kegs sold by reporting companies and an estimate of sales by nonreporting companies. These figures represent a decrease of 9 per cent in volume of sales when compared with the same months in 1926. Of the total amount sold 86 per cent was for coal-mining operations (10 per cent for anthracite and 76 per cent for bituminous coal mining) while the remaining 14 per cent was used for metal mining, quarrying, construction work, and all other purposes. Of 265 pounds of all classes of explosives used per thousand tons of coal produced at bituminous coal mines since

---

[1] Statistician, Bureau of Mines, Department of Commerce.

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

January first, 174 pounds (66 per cent) were black blasting powder. At the anthracite mines where an average of 742 pounds of all classes of explosives were used per thousand tons, 175 pounds (24 per cent) were black blasting powder. States consuming the largest quantities of black blasting powder during the current year were Pennsylvania, Illinois, Kentucky, West Virginia, Indiana, and Ohio.

OTHER HIGH EXPLOSIVES: The quantity of high explosives sold from January to May 1927 amounted to 124,330,000 pounds. This amount includes 116,820,269 pounds sold by reporting companies and an estimate for several companies that do not furnish monthly reports of sales to the Bureau. The amount of high explosives sold thus far in 1927 shows an increase of 3 per cent over the same five months in 1926. Coal mining consumed 12 per cent of this class of explosives (9 per cent being used in anthracite mines and 3 per cent in bituminous mines), metal mining used 32 per cent, and quarrying and nonmetallic mineral mining 27 per cent. The remaining 29 per cent was for railway and other construction work and miscellaneous purposes. At bituminous mines since January 1st 265 pounds of all kinds of explosives have been used for each thousand tons of coal produced, and of this quantity 14 pounds (5 per cent) were high explosives other than permissibles. At anthracite mines 742 pounds of all kinds of explosives per thousand tons of coal have been used thus far this year, and of this quantity 338 pounds (45 per cent) were "high" explosives. The States using the largest quantities of this class of explosives were Pennsylvania, Michigan, California, New York, Oklahoma, Minnesota, Florida, Missouri Ohio, Alabama, Utah, Texas, Washington, Kansas, and Illinois. Each one of these fifteen States sold over 3,000,000 pounds.

EXPLOSIVES USED AT COAL MINES: Special attention is called to Table E, "Yearly sales of explosives to coal mines compared with yearly production of coal," as it shows the average number of pounds of explosives used per thousand tons of coal produced in 1926 and previous years, for bituminous mines, anthracite mines, and for both classes of mines combined. These figures have not heretofore been available for years previous to 1917. The table as now presented contains a complete record, so far as figures can be obtained, of the consumption of explosives in relation to production of coal.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in May were more than 277,600 kegs, showed that the mills were operated to 29 per cent of their capacity in May as compared with 31 per cent in April, 36 per cent in March, and 31 per cent in May last year. The amount of explosives remaining on hand at the close of May represented 49 per cent of one month's manufacturing capacity of the mills reporting, as compared with 47 per cent at the close of May a year ago.

	May, 1926	May, 1927	Jan.-May, 1927
Capacity (Kegs)......	953,583	796,083	3,980,415
Manufactured.........	291,997	230,605	1,624,694
Per cent of capacity.	31	29	41
Shipments............	270,773	284,950	1,640,968
Per cent of capacity.	28	36	41
Sales................	265,087	277,671	1,625,535
Per cent of capacity.	28	35	41
Stocks, end of month.	444,098	393,250	393,250
Per cent of capacity.	47	49	9.8

The following percentage figures show the extent of capacity to which mills manufacturing black powder were operated in 1924, 1925, 1926, and in the months of January to May 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month.

	Manufactured	Shipments	Sales	Stocks
Year 1924...........	41	41	41	3.8
Year 1925...........	38	39	38	3.2
Year 1926...........	40	40	39	3.6
Average, 5 mos. 1926	39	37	37	9.3
1927				
January.............	54	55	56	50
February............	54	47	45	58
March...............	36	36	38	53
April...............	31	32	30	57
May.................	29	36	35	49
Average, 5 months...	41	41	41	9.8

Reports from 22 mills that sold more than 27 million pounds of permissibles and other high explosives in May showed that the mills were operated to 73 per cent of their capacity in May as compared with 66 per cent in April, 64 per cent in March, and 69 per cent in May last year. The amount of explosives remaining on hand at the close of May represented 18 per cent of one month's manufacturing capacity of the mills reporting, as compared with 15 per cent at the close of May a year ago.

	May, 1926	May, 1927	Jan.-May, 1927
Capacity (Pounds)....	39,153,332	38,945,000	194,725,000
Manufactured.........	27,055,468	28,403,146	126,932,503
Per cent of capacity.	69	73	65
Shipments............	28,608,231	28,231,138	126,656,176
Per cent of capacity.	73	72	65
Sales................	26,878,942	27,018,791	120,972,431
Per cent of capacity.	69	69	62
Stocks, end of month.	5,707,181	6,952,865	6,952,865
Per cent of capacity.	15	18	3.5

The percentage of full-time capacity to which mills manufacturing permissibles and other high explosives were operated in 1924, 1925, 1926, and in the months of January to May 1927, is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining on hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924..........	62	62	59	1.4
Year 1925..........	62	62	59	1.5
Year 1926..........	68	68	64	1.4
Average, 5 mos. 1926	63	63	60	2.9
1927				
January............	59	58	57	19
February...........	63	62	57	20
March..............	64	64	62	20
April..............	66	69	65	17
May................	73	72	69	18
Average, 5 months...	65	65	62	3.5

PYROTOL: During the first five months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 7,829,210 pounds of pyrotol of which 1,365,600 pounds represented shipments in May. During the corresponding five months last year the shipments amounted to 8,755,900 pounds. Most of the pyrotol shipped was for use by farmers in clearing land. Table D shows the amount of pyrotol shipped to each State in May 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal-mining operations in each State from January to May, 1927 is shown in Table C. Table D shows the quantity of pyrotol distributed in May to the various States. Table E shows the yearly sales of explosives to coal mines compared with yearly production of coal. -- Reports of Investigations, Department of Commerce, Bureau of Mines.

TABLE A. - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during May, 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	9,331	744,919	374,150
Alaska	200	215,560	2,000
Arizona	2,100	112,575	-
Arkansas	4,468	134,790	16,200
California	8,334	1,628,690	-
Colorado	3,651	499,996	28,500
Connecticut	14	181,900	-
Delaware	-	5,325	-
Florida	1,793	804,550	-
Georgia	2,675	218,600	-
Idaho	1,134	342,965	-
Illinois	3,403	851,923	4,200
Indiana	20,865	292,025	40,300
Iowa	1,808	268,375	800
Kansas	3,949	642,495	3,200
Kentucky	61,486	538,100	317,550
Louisiana	-	194,120	24,450
Maine	584	84,900	-
Maryland & D.C.	14	242,900	16,350
Massachusetts	332	111,750	-
Michigan	1,810	2,006,175	-
Minnesota	4,857	1,267,100	-
Mississippi	32	95,200	-
Missouri	2,449	832,889	20,400
Montana	2,009	476,195	-
Nebraska	20	17,550	-
Nevada	4,150	268,600	-
New Hampshire	91	22,075	-
New Jersey	1	307,350	-
New Mexico	1,403	48,850	24,000
New York	1,374	1,540,965	-
N. Carolina	2,313	338,575	-
N. Dakota	65	8,600	-
Ohio	14,720	1,238,550	22,800
Oklahoma	8,827	868,639	34,524
Oregon	1,696	482,950	-
Pennsylvania	89,025	4,526,841	2,782,800
Rhode Island	-	2,700	-
S. Carolina	332	113,200	-
S. Dakota	20	125,920	-
Tennessee	9,262	358,025	15,800
Texas	8,508	970,020	-
Utah	1,150	808,425	64,950
Vermont	22	95,450	-
Virginia	3,187	352,550	70,050
Washington	5,291	634,965	51,550
West Virginia	47,580	456,300	1,274,000
Wisconsin	458	708,200	-
Wyoming	1,590	118,900	39,550
TOTAL MAY 1927	338,433	27,208,177	5,228,124

2887

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first five months of 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	47,036	3,694,094	2,151,650
Alaska	200	930,790	56,700
Arizona	7,905	683,325	-
Arkansas	20,819	617,506	52,300
California	29,494	6,820,385	-
Colorado	22,373	2,172,711	315,800
Connecticut	89	650,350	-
Delaware	-	27,770	-
Florida	10,114	4,462,622	-
Georgia	7,169	916,600	-
Idaho	2,090	1,722,009	8,850
Illinois	307,914	3,101,378	955,650
Indiana	206,979	1,320,325	222,825
Iowa	54,485	1,001,625	2,450
Kansas	88,147	3,333,281	153,965
Kentucky	280,603	1,801,625	1,494,600
Louisiana	350	1,046,186	48,750
Maine	826	273,050	-
Maryland & D.C.	10,425	986,550	71,750
Massachusetts	783	480,475	-
Michigan	3,204	8,608,050	-
Minnesota	8,697	4,693,358	-
Mississippi	1,032	544,900	-
Missouri	32,456	3,932,289	75,246
Montana	21,451	2,763,165	11,000
Nebraska	1,270	72,725	-
Nevada	15,376	1,387,975	200
New Hampshire	190	49,025	-
New Jersey	21	1,181,375	-
New Mexico	6,242	259,825	144,050
New York	5,535	5,822,224	15,900
N. Carolina	13,598	1,686,975	3,000
N. Dakota	7,521	52,232	5,775
Ohio	115,059	4,351,170	87,250
Oklahoma	46,441	4,880,992	98,141
Oregon	6,973	1,660,325	-
Pennsylvania	413,464	19,241,082	13,563,730
Rhode Island	67	12,350	-
S. Carolina	1,450	354,400	-
S. Dakota	231	581,405	1,300
Tennessee	46,096	1,664,200	156,450
Texas	41,144	3,438,328	2,400
Utah	6,410	3,517,525	352,650
Vermont	2,069	223,150	-
Virginia	28,815	1,629,725	581,400
Washington	16,374	3,336,092	259,825
West Virginia	218,209	2,094,425	5,975,400
Wisconsin	2,256	2,233,550	50
Wyoming	10,500	524,775	385,900
TOTAL 1st 5 MOS. 1927	2,171,952	116,820,269	27,254,957

MAY, 1927

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs	Pounds	Pounds
Quantity used for:			
Coal mining....................	261,973	3,012,419	4,903,673
Metal Mining..................	10,406	7,721,511	2,150
Quarrying and nonmetallic mineral mining................	23,516	7,962,872	43,625
Railway and other construction work..........................	25,266	4,267,390	33,900
All other purposes.............	17,272	4,243,985	244,776
TOTAL MAY 1927...................	338,433	27,208,177	5,228,124

JANUARY TO MAY, 1927, INCLUSIVE.

Quantity used for:			
Coal mining....................	1,871,614	13,809,001	26,133,205
Metal mining..................	29,076	37,560,815	23,975
Quarrying and nonmetallic mineral mining................	100,408	31,965,091	213,495
Railway and other construction work..........................	98,782	17,702,372	89,020
All other purposes.............	72,072	15,782,990	790,262
TOTAL 1st 5 MOS. 1927............	2,171,952	116,820,269	27,254,957

TABLE C - Quantity of explosives sold for use in COAL MINES in May 1927 by Manufacturers rendering monthly reports.

(Including cumulative figures for the first five months of 1927)

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama........	6,599	36,265	50,794	256,144	372,400	2,134,800
Arkansas.......	4,445	20,499	1,400	22,150	1,000	6,300
Colorado.......	925	15,470	7,650	73,225	25,900	291,950
Illinois.......	3,120	304,759	350	168,850	2,000	875,025
Indiana........	19,893	203,236	16,850	185,650	37,400	204,525
Iowa...........	958	51,764	4,575	56,900	500	1,000
Kansas.........	3,608	85,288	31,550	276,251	2,800	153,015
Kentucky.......	56,061	266,281	109,000	389,750	272,650	1,359,280
Maryland.......	---	8,016	11,000	18,500	4,100	42,900
Michigan.......	1,040	2,117	4,050	20,900	---	---
Missouri.......	796	24,864	8,575	61,050	---	26,846
Montana........	2,004	14,884	4,000	4,150	---	4,000
New Mexico.....	900	1,905	---	5,350	24,000	143,550
North Dakota...	32	7,271	3,075	32,850	---	5,775
Ohio...........	11,129	100,291	45,525	207,675	3,700	26,700
Oklahoma.......	7,548	41,734	3,800	59,400	30,698	84,579
Penna. (Bitum).	29,792	156,949	109,450	602,900	917,450	5,673,185
Tennessee......	7,274	40,184	6,450	76,600	15,350	149,600
Texas..........	1,120	11,393	650	3,400	---	---
Utah...........	---	---	800	27,550	62,950	346,150
Virginia.......	2,366	23,654	10,650	114,000	67,350	569,850
Washington.....	1,600	6,524	3,500	27,200	32,900	175,400
West Virginia..	43,767	207,137	78,750	385,300	1,166,600	5,764,725
Wyoming........	1,025	7,367	350	22,800	19,550	325,900
Other States...	1,680	3,335	2,950	26,925	2,000	67,850
Total (Bitum)..	207,682	1,641,187	515,744	3,125,470	3,061,298	18,432,705
Penna. (Anth)..	54,291	230,427	2,496,675	10,683,531	1,842,375	7,700,500
Grand Total as reported....	261,973	1,871,614	3,012,419	13,809,001	4,903,673	26,133,205
Est. total inc. non-reporting companies	Anth.	235,100		11,376,000		7,711,000
	Bitum.	1,674,600		3,332,000		18,460,000
Total reported plus estimate..		1,909,700		14,708,000		26,171,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period May 1, 1927 to May 31, 1927

State	State Highway Departments Roads	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
Alabama..........	2,000	-	-	-	2,000
Alaska...........	-	-	-	50,000	50,000
California.......	-	-	2,000	40,000	42,000
Idaho............	-	16,500	-	20,000	36,500
Iowa.............	-	57,000	-	-	57,000
Maryland.........	-	400	-	-	400
Michigan.........	-	96,000	-	-	96,000
Minnesota........	4,000	278,000	-	-	282,000
North Carolina...	16,000	-	-	-	16,000
Oregon...........	38,000	38,400	4,000	131,000	211,400
South Dakota.....	30,000	-	-	-	30,000
Tennessee........	20,000	-	-	2,000	22,000
Utah.............	-	-	-	21,900	21,900
Washington.......	52,000	86,200	20,000	83,200	241,400
West Virginia....	-	-	-	2,000	2,000
Wisconsin........	-	253,000	-	-	253,000
Wyoming..........	-	-	-	2,000	2,000
Total May........	162,000	825,500	26,000	352,100	1,365,600
Total April......	281,550	1,669,550	7,500	222,000	2,180,600
Total March......	249,500	1,916,860	-	108,700	2,275,060
Total February...	170,750	1,020,150	-	-	1,190,900
Total January....	93,000	704,050	-	20,000	817,050
Grand Total......	956,800	6,136,110	33,500	702,800	7,829,210

TABLE 3.-- Yearly sales of explosives to coal mines compared with yearly production of coal

ALL COAL MINES

Year	Production of coal (short tons)	Pounds of explosives sold to coal mines			Pounds of explosives used per 1,000 tons of coal mined.1/			
		Permissible explosives	High explosives	Black powder	Per.	High	B.P.	Total
1901	293,299,816	–	–	–	–	–	–	–
1902	301,590,434	11,300	Short flame –	–	–	–	–	–
1903	357,356,416	288,661	–	–	1	–	–	–
1904	351,816,398	608,270	–	–	2	–	–	–
1905	392,722,635	1,031,300	–	–	3	–	–	–
1906	414,157,278	1,533,575	–	–	4	–	–	–
1907	480,363,424	2,095,244	–	–	4	–	–	–
1908	415,842,698	2,108,610	–	–	5	–	–	–
1909	460,814,616	8,942,857	–	–	19	–	–	–
1910	501,596,378	11,820,836	–	–	24	–	–	–
1911	496,371,126	13,428,239	–	–	27	–	–	–
1912	534,466,580	18,150,618	20,903,430	187,091,000	34	39	350	423
1913	570,048,125	21,804,285	24,143,133	184,917,075	38	42	325	405
1914	513,525,477	19,593,892	24,215,945	176,812,650	38	47	345	430
1915	531,619,487	21,841,659	22,384,025	167,513,950	41	42	315	398
1916	590,098,175	26,566,521	20,901,405	176,976,025	45	35	300	380
1917	651,402,374	32,910,397	28,262,807	235,750,300	51	43	362	456
1918	678,211,904	37,262,915	30,780,188	216,221,550	55	45	319	419
1919	553,952,259	32,840,196	29,616,383	153,490,125	59	53	277	389
1920	658,264,932	45,222,130	37,273,255	219,762,625	69	56	334	459
1921	506,395,401	38,055,650	34,231,542	140,335,875	75	68	277	420
1922	476,951,121	40,197,939	25,497,758	154,761,950	84	53	324	461
1923	657,903,671	56,806,709	37,828,979	175,488,750	87	57	267	411
1924	571,613,400	52,147,201	36,608,067	140,625,050	91	64	246	401
1925	581,869,890	52,256,042	26,946,969	132,413,800	90	46	228	364
1926	2/663,290,000	65,143,319	35,228,899	136,112,400	98	53	205	356
		Anthracite Mines						
1909	81,070,359	394,294	–	–	11	–	–	–
1910	84,485,236	1,486,100	–	–	18	–	–	–
1911	90,464,067	1,917,412	–	–	21	–	–	–
1912	84,361,598	2,177,172	13,618,433	43,058,925	26	162	510	698
1913	91,524,922	3,294,225	15,583,573	43,151,900	36	170	472	678
1914	90,821,507	4,380,635	16,755,461	45,584,750	48	185	502	735
1915	88,995,061	5,037,050	15,972,340	43,336,375	57	179	487	723
1916	87,578,493	5,219,032	13,888,875	36,204,300	60	159	413	632
1917	99,611,811	7,298,925	16,074,125	35,754,225	73	162	359	594
1918	98,826,084	7,654,250	16,709,256	30,304,300	77	169	307	553
1919	88,092,201	8,579,643	17,800,259	25,467,125	98	202	289	589
1920	89,598,249	8,558,690	19,278,375	23,085,575	95	215	258	568
1921	90,473,451	11,921,675	22,832,825	23,861,275	132	252	264	648
1922	54,683,022	7,197,596	12,480,611	12,625,300	132	228	231	591
1923	93,339,009	14,597,560	25,539,570	21,743,550	156	274	233	663
1924	87,926,862	16,895,771	26,846,846	20,094,500	192	305	229	726
1925	61,817,149	12,080,115	17,818,772	12,705,425	195	288	206	689
1926	2/85,000,000	19,121,700	26,168,938	16,934,950	225	308	199	732
		Bituminous Mines						
1909	379,744,257	8,048,563	–	–	21	–	–	–
1910	417,111,142	10,334,736	–	–	25	–	–	–
1911	405,907,059	11,510,827	–	–	28	–	–	–
1912	450,104,982	15,973,446	7,284,997	144,032,075	36	16	320	372
1913	478,523,203	18,510,060	8,559,560	141,765,175	39	18	296	353
1914	422,703,970	15,213,257	7,460,484	131,227,900	36	18	310	364
1915	442,624,426	16,804,609	6,411,685	124,177,575	38	14	281	333
1916	502,519,632	21,347,489	7,012,530	140,771,725	43	14	280	337
1917	551,790,563	25,611,472	12,188,682	199,996,075	47	22	362	431
1918	579,385,820	29,608,665	14,658,817	185,917,250	51	25	321	397
1919	465,860,058	24,260,553	11,816,124	128,023,000	52	25	275	352
1920	568,666,683	36,663,440	17,994,880	196,677,050	64	32	346	442
1921	415,921,950	26,133,975	11,398,717	116,474,600	63	27	280	370
1922	422,268,099	33,000,343	13,017,147	142,136,650	78	31	337	446
1923	564,564,662	42,209,149	12,289,409	153,745,200	75	22	272	369
1924	483,686,538	35,251,430	9,761,221	120,530,550	73	20	249	342
1925	520,052,741	40,175,927	9,128,197	119,708,375	77	18	230	325
1926	2/578,290,000	46,021,619	9,059,961	119,177,450	79	16	206	301

1/- The figures show the relation that the consumption of each class of explosives bears to the total quantity of explosives used in producing coal; they do not indicate the quantity of coal broken down by any given quantity of explosives. The figures are the quotient obtained by dividing the total quantity of explosives used at all coal mines by the number of tons of coal produced at all mines in the United States. 2/- Estimated.

622.09
Un 32 mo
cop. 2

STATE GEOLOGICAL SURVEY.

DEPARTMENT OF COMMERCE

BUREAU OF MINES

ISSUED DURING JULY, 1927

Reports of Investigations

Serial No. 2817 - Desulphurizing Action of Manganese in Iron. By C. H. Herty, Jr., and J. M. Gaines, Jr.

Serial No. 2818 - Permissible Explosives Approved Prior to June 30, 1927. By G. St. J. Perrott and S. P. Howell.

Serial No. 2819 - Apparatus for Vacuum Distillation of Lubricating and Heavy Petroleum Oils. By Martin J. Gavin and Arch. L. Foster.

Serial No. 2820 - The Wire Saw in Slate Quarrying. Preliminary Report. By Oliver Bowles.

Serial No. 2821 - Coal-Mine Fatalities in June, 1927. By W. W. Adams.

Serial No. 2822 - The Use of Solvents for Dewaxing Paraffin-Base Crude Oil. By H. M. Smith.

Serial No. 2823 - Consumption of Explosives in June, 1927. By W. W. Adams.

Compiled by Harry E. Tufft, Information Service.

Copies of any of these papers may be obtained by writing to the Bureau of Mines, Washington, D. C. Please request by number or check the desired reports above and return this list.

NAME .... STREET ....

CITY .... STATE ....

3007

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

Serial No. 2817
July, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE --- BUREAU OF MINES

DESULPHURIZING ACTION OF MANGANESE IN IRON

By C. H. Herty, Jr.,[1] and J. M. Gaines, Jr.[2]

It is generally recognized that the presence of manganese in pig iron tends to prevent high-sulphur concentrations.[3] Further, this beneficial influence is commonly credited to the formation of MnS, which, being sparingly soluble, tends to separate from the liquid iron.

This action of manganese is of considerable importance, therefore, to the maker of pig iron, whether for foundry uses or for steel-making. Of recent years, the tendency of furnace operators has been to charge a higher percentage of manganese, and it seems probable that this course has been adopted partly in recognition of the desulphurizing action of this constituent. Both in the transfer ladle and in the mixer, a lowering of the sulphur content has been noted. McCance[4] reports the following analyses taken at cast and again from the same iron on pouring from the mixer one hour later:

		At cast	One hour later
I	Mn, per cent	1.00	0.80
	S, per cent	0.070	0.038
II	Mn, per cent	1.20	1.00
	S, per cent	0.060	0.030

Wheaton[5] followed a month's campaign on a furnace producing high-manganese, high-sulphur iron. The iron was sampled at cast and again just before the transfer ladles were emptied into the mixer. His results were:

Manganese range	Per cent S at furnace	Per cent S at mixer
1.00 - 1.50 per cent (av. 1.39)	0.087	0.041
1.50 - 2.00 per cent (av. 1.72)	0.070	0.035
2.00 - (av. 2.13)	0.073	0.031

---

[1] - Physical chemist, Pittsburgh Experiment Station, Bureau of Mines.

[2] - Assistant physical chemist, Pittsburgh Experiment Station.

[3] - Stead, J. E., Jour. Iron & Steel Inst., No. 2, 1892, p. 216; McCance, A., Jour. Iron & Steel Inst., No. 1, 1918, p. 243.

[4] - McCance, A., Reference cited.

[5] - Yearbook, Amer. Iron & Steel Inst., 1920, p. 393.

This brings out very clearly the fact that the higher the manganese the lower will be the residual sulphur.

Wheaton's findings were verified by Herty and Gaines,[6] who followed the same procedure and concluded from their data that the relation of manganese to residual sulphur was one which could be expressed by the equation:

K = (per cent Mn) x (per cent residual S) = 0.070. It was added that this relation would be valid only when the iron had previously contained more than the equilibrium concentrations of manganese and sulphur, and when resulphurization by furnace slag was prevented. The temperature for these observations averaged 2400° F. (1315° C.).

The values for K from Wheaton's data are:

Per cent Mn	Per cent S	K
1.39	0.041	0.057
1.72	0.035	0.060
2.13	0.031	0.066

These show a fair agreement among themselves and are only slightly below the value 0.070 reported by Herty and Gaines.

The fact that the concentrations of manganese and sulphur obeyed a relationship defined by an equilateral hyperbola

$$xy = c,$$

at once suggested the familiar law of the solubility product, as exemplified by the conduct of slightly soluble salts in water. As molten iron is a good dielectric it should be an ionizing medium, and the manganese sulphide in the melt should be dissociated into ions in equilibrium with the solid salt, which has crystallized out. It is unfortunate that in neither of the two researches quoted was a sample of the slag on the ladle obtained. On this account we do not know definitely that the ions in solution were in equilibrium with solid MnS. It is equally plausible that the MnS, after elimination, formed a slag with silica, MnO, FeO, etc., which might be present on the metal surface. If this were the case, a difference in the composition of this slag would account for the variation between the findings of Wheaton and those of Herty and Gaines.

It is evident that there are other factors besides the concentration of manganese which are influencing desulphurization. The problem is really a study of the bivariant system, Fe-Mn-S, the three phases being the vapor, the metal, and as the third either a solid or a liquid MnS slag. Therefore, at a given temperature there will be definite relations existing between the compositions of the three phases. As we are ignorant of conditions in the vapor phase, we are confined to consideration of equilibrium between slag and metal. This reasoning shows us that our other factors will most certainly include the

---

[6] - Herty, C. H., Jr., and Gaines, J. M., Jr., Desulphurizing Action of Manganese in Iron. Trans. Amer. Inst. Min. & Met. Eng., October, 1926.

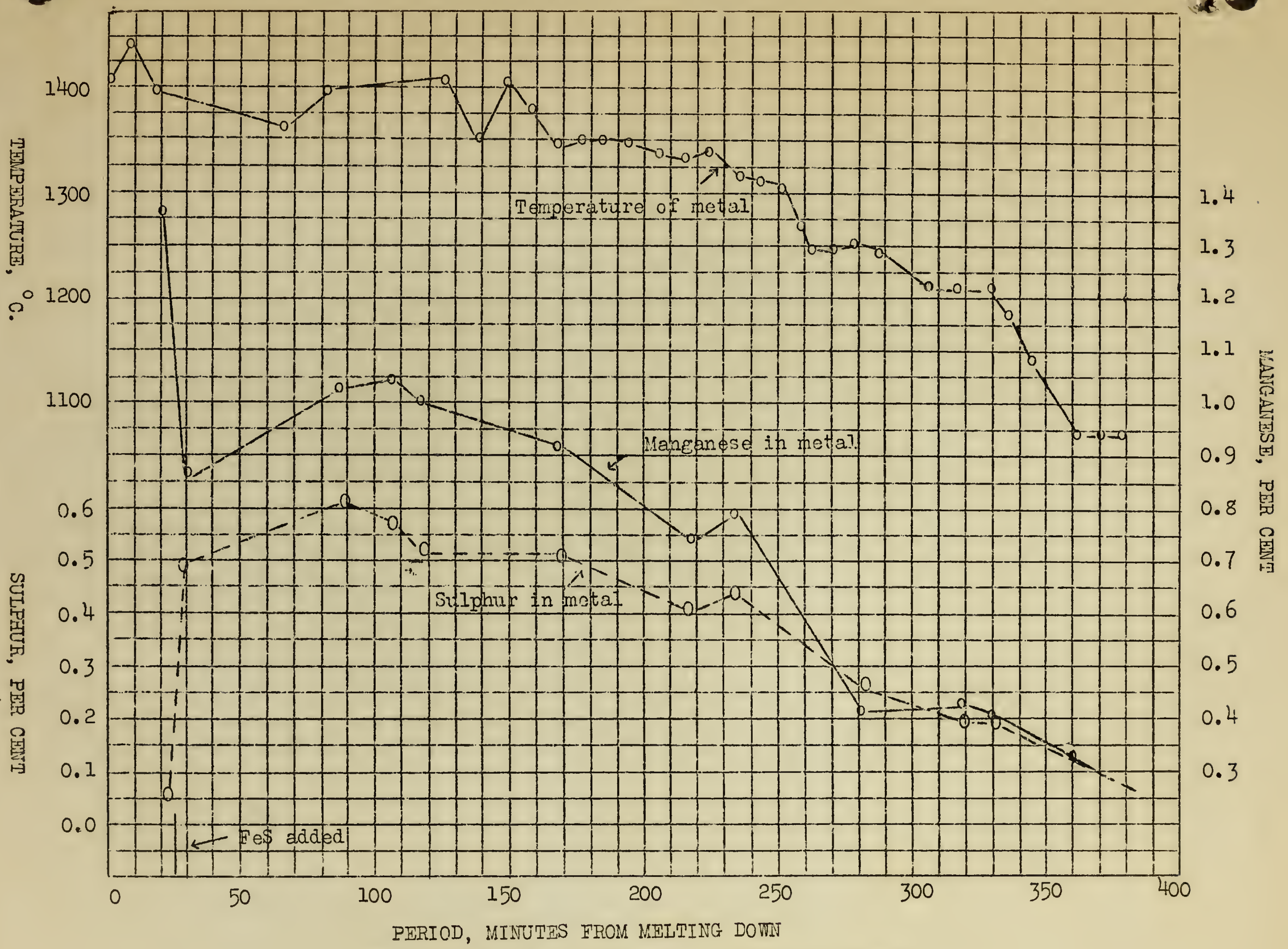


Fig. 1 - Run 9 solubility of manganese sulphide.

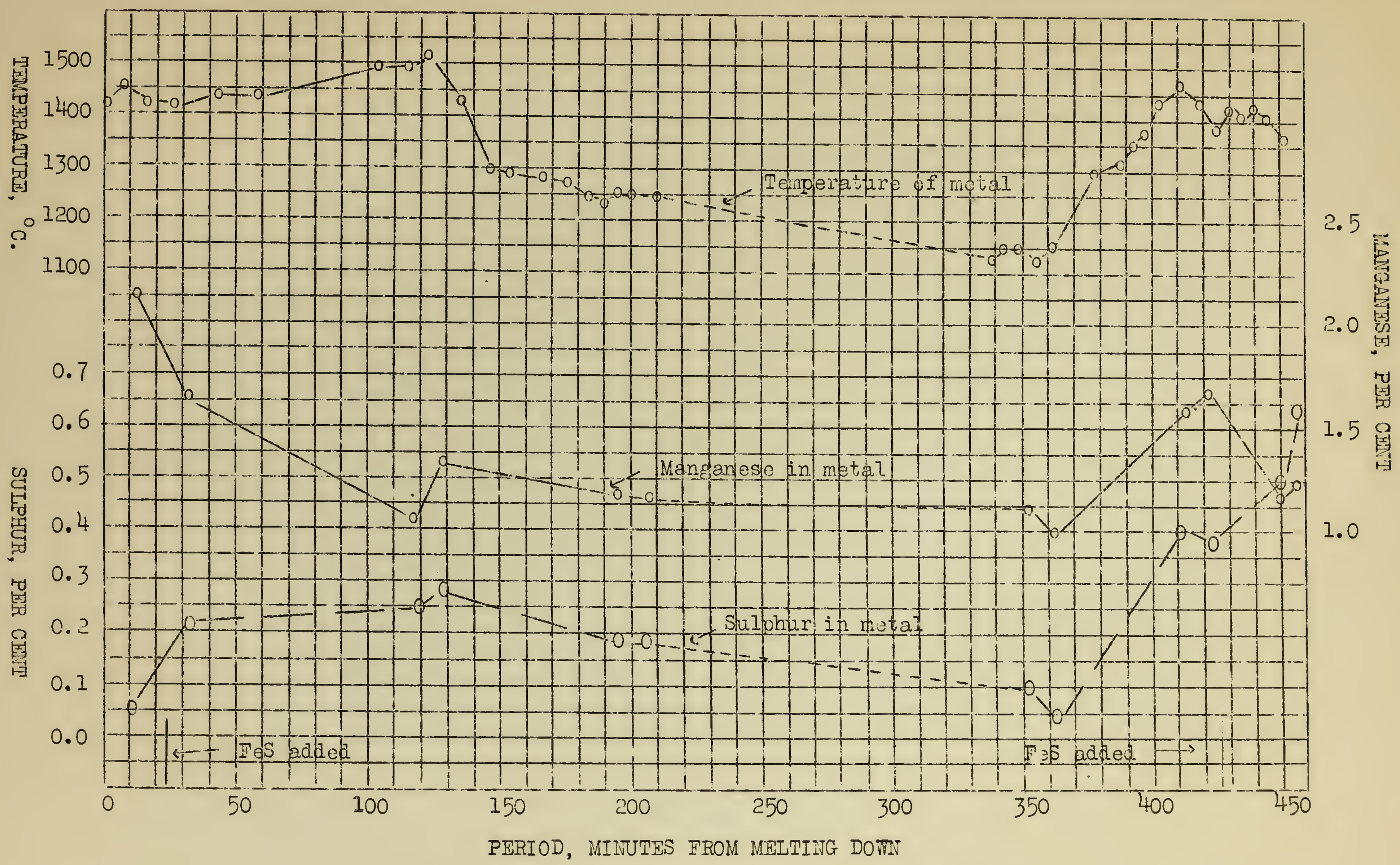


Fig. 2 - Run 10 solubility of manganese sulphide.

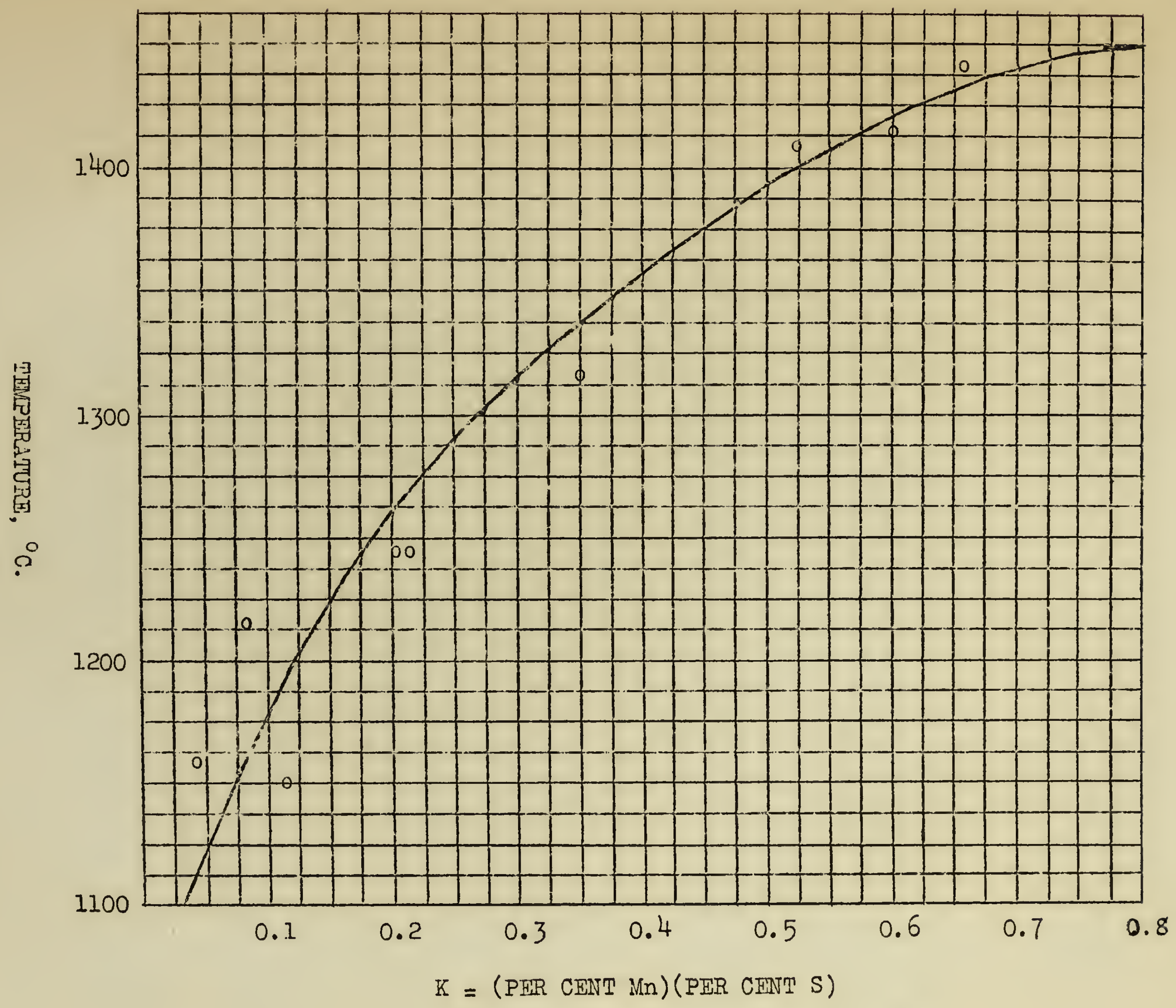


Fig. 3 - Effect of temperature on solubility of MnS, from runs 9 and 10.

temperature and slag composition, and possibly the effect of other substances in the solutions. The present report deals only with the first-named variable, temperature. No attempt was made to control slag composition, except to carry out all determinations under as nearly identical conditions as possible. The effect of temperature is so striking that it seemed advisable to make several preliminary runs, without regard to the slag, in order to verify the influence of the former.

Procedure.

In carrying out the determinations, an Ajax-Northrup high-frequency induction furnace of about 100 pounds capacity was used. A charge of boiler punchings and petroleum coke was melted in a graphite crucible, with enough ferro-silicon to give samples that could easily be drilled. Ferro-manganese in the desired amount was next added and the metal surface was covered with coke to prevent oxidation. Temperatures were measured with a disappearing filament pyrometer sighted on the bottom of a closed silica tube inserted in the iron. No correction for emissivity was employed.[7] When the temperature reached the desired level, a predetermined quantity of iron sulphide was added. Samples were taken with the temperature falling, in order to be sure that saturation of the iron with MnS was attained.

Results.

Several preliminary runs were carried out during the process of overcoming experimental difficulties, but these are not included here. The data are generally unreliable for one or more of the following reasons:

1. Failure to reach equilibrium, or saturation.
2. Uncertainty as to temperature measurements.
3. Resulphurization due to oxidation.
4. Mechanical difficulties.

Some of the first runs will be briefly referred to, as bringing out points of interest, and the last two runs, together with calculated results and conclusions, will be discussed in detail. The graphic log-sheets are shown in Figures 1 and 2. (See also Tables 1 and 2.)

In both, a sharp drop in percentage of Mn is evident on the addition of FeS, followed by an increase in percentage of Mn to its equilibrium value for that temperature. Thereafter the temperature was gradually lowered with consequent drop in the manganese and sulphur concentrations. At the end of run No. 10 (Figure 2) the temperature was raised again, causing both the manganese and sulphur in the metal to rise. When additional FeS was added, the manganese dropped, while the sulphur increased. Run No. 9 (Figure 1) covers the range 0.30 to 1.05 per cent Mn and run No. 10 from 1.00 to 1.75 per cent Mn. The results, calculated from the analyses, are shown in Figure 3, where the constant

---

[7] - Cf. Bureau of Standards Technical Paper No. 170, p. 118.

K (per cent Mn x per cent S) is plotted against the temperature. (See also Tab 3.) The points all fall reasonably close to a smooth curve, which shows how rapidly the quantity of dissolved MnS increases with temperature.

TABLE 1. - Results of run No. 9.

Time, minutes	Temperature, °C.	Sample	Per cent					K
			Mn	S	C	Si	P	
22	1400	1	1.36	0.064	4.56	2.53	0.026	0.087
29	1400	2	0.86	0.50	4.73	2.40	-	0.430
89	1400	3	1.04	0.62	-	-	-	0.645
107	1400	4	1.07	0.58	-	-	-	0.620
117	1410	5	1.01	0.52	4.36	2.47	0.027	0.525
169	1350	6	0.93	0.52	-	-	-	0.483
219	1340	7	0.75	0.41	-	-	-	0.307
234	1320	8	0.80	0.44	4.53	2.46	-	0.352
292	1250	9	0.42	0.26	-	-	-	0.109
321	1215	10	0.43	0.20	-	-	-	0.086
332	1215	11	0.41	0.20	4.05	2.52	-	0.082
368	1100	12	0.30	0.10	3.72	2.48	0.031	0.030

TABLE 2. - Results of run No. 10.

Time, minutes	Temperature, °C.	Sample	Per cent					K
			Mn	S	C	Si	P	
11	1440	1	2.14	0.062	4.45	-	0.038	0.132
30	1425	2	1.64	0.220	4.82	1.79	-	0.361
119	1500	3	1.06	0.253	4.43	-	-	0.268
128	1495	4	1.34	0.286	4.50	-	-	0.370
197	1245	5	1.17	0.182	4.66	-	-	0.213
207	1245	6	1.15	0.179	4.31	-	-	0.206
353	1150	7	1.14	0.100	4.09	1.74	-	0.114
363	1160	8	1.03	0.044	3.98	1.78	-	0.045
412	1435	9	1.62	0.410	5.64	3.14[a]	-	0.665
422	1420	10	1.69	0.389	5.08	3.82[a]	-	0.656
449	1415	11	1.20	0.504	4.72	3.09[a]	-	0.605
456	1390	12	1.26	0.634	4.75	2.55[a]	0.030	0.798

[a] Increase in per cent Si is due to reduction of silica tube used in temperature measurements.

TABLE 3. - Data compiled for Figure 3.

Run No.	Sample No.	Temperature, $^{\circ}$C.	K	Mn, per cent	S, per cent
9	12	1100	0.030	0.30	0.100
10	7	1150	0.114	1.14	0.100
10	8	1160	0.045	1.03	0.044
9	11	1215	0.082	0.41	0.20
10	5	1245	0.213	1.17	0.182
10	6	1245	0.206	1.15	0.179
9	8	1320	0.352	0.80	0.44
9	5	1410	0.525	1.01	0.52
10	11	1415	0.605	1.20	0.504
10	9	1440	0.656	1.62	0.389

Two other runs were made in which much higher concentrations of manganese were employed, and where a large amount of the sulphide was eliminated, yielding considerable slag (runs 7 and 8). The product K for these runs is considerably higher than for the two first mentioned, although it shows just as marked a temperature coefficient. These data are not included here for the reason that the slag formed was not sufficiently fluid to permit establishing equilibrium. Furthermore, the temperatures, taken with the optical pyrometer on the free surface of the metal, are not comparable with those in the later runs, due to uncertainty as to the degree of blackness of the object.

Discussion.

It will be noted from Figure 3 that at 2400° F. (1315°C.) the product K is 0.30 in contrast to the value of 0.070 as found by Herty and Gaines. That this difference, as well as that for the high-manganese, high-sulphur runs mentioned above, may be due to differences in slag composition, is shown as follows:

Conditions	I Wheaton) Herty and Gaines) Pig-iron ladles	II Runs 9 and 10 This paper Induction furnace	III Runs 7 and 8 This paper Induction furnace
Amount of MnS eliminated from metal (approx.)	0.03-0.15 per cent	1.7 per cent	10-12 per cent
K at 1300° C.	0.065-0.070	0.30	0.66 (approx.)

It will be seen that in cases where large amounts of MnS are transferred to the slag, the constant is much higher. In I, we may be fairly sure that there is an appreciable amount of basic slag on the metal surface, which would tend to lower the concentration of MnS in the slag. (The disadvantages of furnace slag on the ladle will be considered later.) In II the conditions are somewhat different on account of the layer of granular coke on the metal. The result of its presence may very probably be that the sulphide upon elimination is absorbed in the porous structure of the coke and there frozen. Pieces of coke have been taken from the crucible which indicated this was the case. In III there is a slag which is quite high in MnS and is also liquid. A slag analysis for these conditions would show 29.5 per cent Mn, 2.3 per cent Fe, 16.9 per cent S, 1.5 per cent CaO, and 0.3 per cent SiO_2.

We know that at equilibrium the vapor pressures of MnS in equilibrium with slag and metal are identical; hence, if there is a difference in the amount of MnS in the metal under three different slags at the same temperature, the conclusion is valid that MnS in these slags has different pressures. Whether this pressure is a linear function of the concentration or a more complex one, depending on possible compound-formation, remains to be seen. It is reasonable to suppose, moreover, that on passing from liquid to solid MnS, one would find a break in the temperature-solubility curve corresponding to the melting point of MnS.

These considerations give some idea of the complex system which must be unraveled before the mechanism of the reaction can be completely known. A continuation of the present work will extend the range of manganese concentration and will also deal with the question of slag composition.

The matter of effect of furnace slag on the ladle has been mentioned. In their work previously referred to Herty and Gaines found that if a considerable quantity of furnace slag was allowed to run into the ladle with the metal, the chances of getting any elimination of sulphur were greatly lessened. This was thought due to oxidation, and subsequent shift of the equilibrium

$$CaO + FeS \rightleftarrows CaS + FeO.$$

An increase in FeO, in the presence of slag, would tend to throw FeS back into the iron. The ease with which resulphurization may take place in the presence of an oxidizing agent was demonstrated in the course of the present investigation. Mention has been made of the fact that a layer of coke covered the metal at all times. The importance of this procedure was not realized in the earlier runs, as the following results show:

Run 1. - By addition of manganese, the percentage of S had been reduced from 0.175 to 0.051. At this point the percentage of C in the metal stopped increasing, even though it was considerably below saturation. From here on there was therefore, evidently, a deficiency of coke on the metal, and the sulphur content gradually rose to 0.112 per cent.

Run 2. - In order to make sure of the effect of oxidation, all coke was removed at the end of the run, causing the sulphur to increase from 0.055 to 0.080 per cent. This would probably have been higher but for the fact that most of the slag was removed with the coke.

Inasmuch as it is practically impossible entirely to exclude furnace slag from the transfer ladle, the importance of maintaining a reducing layer above the metal surface - that is, of anthracite or coke breeze - can not be over-emphasi

Only by so doing can one expect to receive the benefits of the desulphurizing action of manganese, and to prevent even an increase of sulphur in the iron.

Certain blast-furnace operators have claimed that they preferred running the manganese fairly high, because it helped to remove sulphur in the furnace. Some open-hearth men have advanced similar beliefs, and the theory has found credence that manganese will remove sulphur from iron and steel under any and all conditions.

In the light of the data here presented, it may be said, as a first requisite for this action, that the temperature should be fairly low. If we assume that the increase of K with temperature under blast-furnace conditions is proportional to its increase under the conditions of these experiments, we have a means of approximating its value in the blast-furnace hearth. If the temperature here is assumed to be 2650° F. (1450° C.), and K at 2400° F. (1315° C.) is 0.070; and if the relative increase in K, as shown in Figure 3 for this temperature change, is 0.775/0.30 = 2.58; then K at 2650° F. will be 0.070 x 2.58 = 0.181. In other words, if the iron is running 2 per cent manganese, elimination of sulphur in the crucible of the furnace could be expected down to a point where (2 x per cent S) = 0.181, or where per cent S = 0.091. With lower manganese in the iron, the limit on sulphur would of course be higher. This does not mean that with 2 per cent manganese the furnace cannot make better than 0.091 per cent sulphur iron, but that the manganese itself cannot be expected to eliminate sulphur below this point. Obviously, too, at open-hearth temperatures, no elimination of sulphur could be expected, on account of the tremendous increase in K, as predicted by Figure 3.

It is entirely possible that manganese in the blast furnace and in the open hearth may facilitate sulphur elimination by rendering the slag more fluid. However, this cannot truthfully be classed as a desulphurizing action of manganese.

Summary

1. The relation between the temperature and the solubility product, (K = (per cent Mn)(per cent S)) for MnS in iron in contact, presumably, with solid MnS, has been determined over the range 1100-1440° C. and 1.00 per cent Mn to 1.75 per cent Mn. The amount of dissolved MnS increases rapidly with the temperature, the change in the product for this range being from 0.030 to approximately 0.650.

2. The composition of any liquid slag formed is pointed out as a probable factor in determining the magnitude of K.

3. The effect of oxidation on desulphurization is discussed, with examples.

4. The desulphurizing action of manganese in the transfer ladle has been discussed. However, the higher temperatures prevailing within the blast furnace and in the open hearth make it probable , in view of the results here presented, that manganese cannot act in these cases directly as a desulphurizer; it may, and very probably does, assist indirectly other desulphurizing reactions. - Reports of Investigations, Bureau of Mines, Department of Commerce.

STATE GEOLOGICAL [illegible]

Serial No. 2818
July, 1927

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

PERMISSIBLE EXPLOSIVES APPROVED PRIOR TO JUNE 30, 1927.

By G. St. J. Perrott[1] and S. P. Howell[2]

This report of investigation gives a complete list of all permissible explosives on the active list as of June 30, 1927. It totals 135 explosives. The immediately preceding complete list of permissible explosives was given in Technical Paper 376[3], "Permissible Explosives, Mining Equipment and Rescue Apparatus Approved Prior to January 1, 1925," by J. E. Crawshaw, L. C. Ilsley, D. J. Parker and A. C. Fieldner. This publication should be consulted for a description of the class designations. The classes are 1a, ammonium nitrate explosives; 2. hydrated explosives; 3, organic nitrate explosives; 4, nitroglycerin explosives; 5, ammonium perchlorate explosives, and 6, gelatin explosives.

The complete name and address of each manufacturer is indicated in the table as follows:

Apache: Apache Powder Co., Benson, Ariz.
Atlas: Atlas Powder Co., Wilmington, Del.
Austin: Austin Powder Co., Cleveland, O.
du Pont: E. I. du Pont de Nemours & Co., Wilmington, Del.
Equitable: Equitable Powder Manufacturing Co. and
Egyptian Powder Co., East Alton, Ill.
Giant: Giant Powder Co. (Con.), Giant, Calif.
Grasselli: Grasselli Powder Co., Cleveland, O.
Hercules: Hercules Powder Co., Wilmington, Del.
Illinois: Illinois Powder Manufacturing Co., St. Louis, Mo.
Peerless: Peerless Explosives Co., White Haven, Pa.
Puget: Puget Sound & Alaska Powder Co., Everett, Wash.
Trojan: Trojan Powder Co., Allentown, Pa.
Union: Union Explosives Co., Clarksburg, W. Va.

---

[1] Supervising chemist, explosives section, Bureau of Mines, Department of Commerce.

[2] Explosives engineer, Bureau of Mines, Department of Commerce.

[3] Requests for a copy of Technical Paper 376 and Schedule 17A should be addressed to the Bureau of Mines, Washington, D. C.

Permissible Explosives as of June 30, 1927

Brand	Class designation basis		When used with electric detonators of not less efficiency than	Weight of $1\frac{1}{4}$ x 8 inch cartridge	Smallest permissible diameter	Unit deflective charge	Rate of detonation in 1-1/4 inch diameter cartridge		Manufacturer
	Vol. poisonous gases	Characteristic ingredient							
1	2	3	4	5	6	7	8		9
				Grams	Inches	Grams	Ft. per second	Meters per sec.	
Apache Coal Powder A	B	1a	No. 6	137	1-1/4	222	11,710	3,570	Apache
Apache Coal Powder B	B	do.	do.	158	1-1/4	241	8,200	2,500	do.
Apache Coal Powder D, L. F.	A	do.	do.	160	1-1/4	235	10,820	3,300	do.
Apache Coal Powder E, L. F.	A	do.	do.	162	1-1/4	230	11,250	3,430	do.
Apache Coal Powder F, L. F.	A	do.	do.	160	1-1/4	225	11,090	3,380	do.
Apache Coal Powder S	B	do.	do.	181	1-1/8	303	5,710	1,740	do.
Atlas E, L. F.	A	do.	do.	163	7/8	223	7,020	2,140	Atlas
Atlas E, L. F. Special	A	do.	do.	168	1	229	7,280	2,220	do.
Austin Red Diamond No. 9, L. F.	A	do.	do.	134	7/8	223	6,330	1,930	Austin
Austin Red Diamond No. 10, L. F.[1]	B	do.	do.	124	7/8	248	8,070	2,460	do.
Austin Red Diamond No. 2-A, L. F.	A	do.	do.	175	7/8	252	10,760	3,280	do.
Austin Red Diamond No. 4-A, L. F.	A	do.	do.	175	7/8	252	10,760	3,280	do.
Austin Red Diamond No. 6-A, L. F.	A	do.	do.	176	7/8	220	13,610	4,150	do.
Austin Red Diamond No. 1-D, L. F.	A	do.	do.	147	7/8	225	12,430	3,790	do.
Austin Red Diamond B, L. F.[2]	A	do.	do.	147	7/8	205	11,380	3,470	do.
Austin Red Diamond E, L. F.[3]	A	do.	do.	168	7/8	237	6,230	1,900	do.
Austin Red Diamond F, L. F.	B	do.	do.	142	1-1/8	207	8,460	2,580	do.
Austin Red Diamond G, L. F.	A	do.	do.	162	1-1/8	237	6,760	2,060	do.
Austin Red Diamond GG, L. F.[4]	A	do.	do.	151	7/8	218	7,970	2,430	do.
Big Red No. 1	B	do.	do.	171	7/8	240	7,250	2,210	Equitable
Big Red No. 7	A	do.	do.	186	7/8	227	10,000	3,050	do.
Big Red No. 7-A	B	do.	do.	142	1-1/8	207	8,460	2,580	do.
Bituminite 1	C	4	do.	187	1-1/4	318	12,790	3,900	Hercules
Bituminite 5	A	1a	do.	176	1	231	9,120	2,780	do.

---

[1] Same as Monobel No. 10, L. F.

[2] Same as Coalite B, L. F.

[3] Same as Coalite E, L. F.

[4] Same as Coalite G, L. F.

1	2	3	4	5	6	7	8		9
				Grams	Inches	Grams	Ft. per second	Meters per sec.	
Black Diamond No. 2-A	C	4	No. 6	190	1-1/4	281	12,600	3,840	Illinois
Black Diamond No. 3-A	C	do.	do.	156	1-1/4	294	11,150	3,400	do.
Black Diamond No. 5	A	la	do.	180	7/8	288	6,040	1,840	do.
Black Diamond No. 5, L. F.	A	do.	do.	175	7/8	222	8,590	2,620	do.
Black Diamond No. 6, L. F.	C	4	do.	158	1-1/4	306	9,640	2,940	do.
Black Diamond No. 7	A	la	do.	183	7/8	214	10,730	3,270	do.
Black Diamond No. 15	A	do.	do.	160	7/8	217	6,560	2,000	do.
Black Diamond No. 17	A	do.	do.	172	7/8	222	10,790	3,290	do.
Carbonite No. 5	C	4	do.	175	7/8	204	10,140	3,090	du Pont
Carbonite No. 6	C	do.	do.	175	7/8	345	7,480	2,280	do.
Carbonite No. 7	C	do.	do.	150	7/8	334	7,450	2,270	do.
Coalite A, L. F.	A	la	do.	164	7/8	204	11,580	3,530	Atlas-Giant
Coalite B, L. F.	B	do.	do.	147	7/8	205	11,380	3,470	do.
Coalite C, L. F.	A	do.	do.	166	7/8	215	12,200	3,720	do.
Coalite D, L. F.	A	do.	do.	154	7/8	214	12,070	3,680	do.
Coalite E, L. F.	A	do.	do.	168	7/8	237	6,230	1,900	do.
Coalite F, L. F.	A	do.	do.	162	7/8	362	4,620	1,410	do.
Coalite G, L. F.	A	do.	do.	151	7/8	218	7,970	2,430	do.
Coalite H, L. F.	A	do.	do.	184	1	260	6,360	1,940	do.
Coalite I, L. F.	A	do.	do.	164	7/8	267	9,250	2,820	do.
Coalite M, L. F.	B	do.	do.	124	7/8	207	9,640	2,940	do.
Coalite S, L. F.	A	do.	do.	139	1	213	7,710	2,350	do.
Coalite T, L. F.	A	do.	do.	139	7/8	224	5,970	1,820	do.
Coalite Y	B	do.	do.	164	7/8	235	10,300	3,140	do.
Coalite No. 4, L. F.	B	4	do.	150	7/8	307	7,810	2,380	do.
Coal Special 2-W	C	do.	do.	180	1-1/4	277	11,580	3,530	Hercules
Coal Special 3-C	C	do.	do.	192	1-1/4	288	9,770	2,980	do.
Collier B	B	la	do.	156	7/8	207	10,960	3,340	do.
Collier B, L. F.	A	do.	do.	153	7/8	210	11,380	3,470	do.
Collier C, L. F.	A	do.	do.	141	7/8	217	11,970	3,650	do.
Collier X, L. F. 2	A	do.	do.	165	7/8	228	9,970	3,040	do.
Collier 5	A	do.	do.	178	1-1/4	240	8,270	2,520	do.
Collier 5, Special	A	do.	do.	180	1-1/8	236	8,330	2,540	do.
Collier 11	A	do.	do.	165	7/8	217	11,680	3,560	do.
Cronite No. 1	A	do.	do.	149	1-1/4	233	10,500	3,200	Atlas

1	2	3	4	5	6	7	8		9
							Ft. per	Meters	
				Grams	Inches	Grams	second	per sec.	
Duobel No. 2, L. F.	A	1a	No. 6	143	7/8	209	9,970	3,040	du Pont
Duobel, L. F.	A	do.	do.	147	7/8	225	12,430	3,790	do.
Gel-Coalite X, L. F.	A	6	do.	239	7/8	253	9,610	2,930	Atlas
Gel-Coalite Z, L. F.	A	do.	do.	226	7/8	237	16,600	5,060	Atlas-Giant
Gelite 1 L. F.	A	do.	do.	248	1-1/4	255	8,330	2,540	Grasselli
Gelobel	A	do.	do.	236	7/8	259	15,250	4,650	Du Pont
General 1	A	1a	do.	168	7/8	208	10,660	3,250	do.
General 6-X	A	do.	do.	194	1-1/8	220	10,500	3,200	do.
Giant E, L. F.	A	do.	do.	163	7/8	223	7,020	2,140	Giant
Giant E, L. F. Special	A	do.	do.	168	1	229	7,280	2,220	do.
Grasselli LC, L. F.	A	do.	do.	160	7/8	216	5,940	1,810	Grasselli
Grasselli 2 L. F.	B	do.	do.	142	7/8	221	10,860	3,310	do.
Grasselli 5 L. F.	A	do.	do.	156	7/8	223	7,680	2,340	do.
Grasselli 6 L. F.	A	do.	do.	162	7/8	218	9,220	2,810	do.
Grasselli 7 L. F.	A	do.	do.	131	7/8	217	8,000	2,440	do.
Grasselli 8 L. F.	A	do.	do.	158	7/8	223	9,640	2,940	do.
Hercogel	A	6	do.	241	1	257	8,690	2,650	Hercules
Hercules Coal Powder 2	A	1a	do.	186	1-1/8	212	9,280	2,830	do.
Lomite No. 1	B	2	do.	176	1-1/4	300	13,940	4,250	Atlas
McAbee Y	B	1a	do.	149	1-1/8	228	10,860	3,310	do.
McAbee Z	A	do.	do.	151	1-1/8	212	10,590	3,230	do.
Mine-Gel No. 1[5]	A	6	do.	248	1-1/4	255	8,330	2,540	Grasselli
Mine-ite No. 5-D	A	1a	do.	161	7/8	241	8,720	2,660	do.
Mine-ite No. 6-D	B	do.	do.	169	7/8	224	8,100	2,470	do.
Miners Friend No. 1	B	do.	do.	167	7/8	223	11,580	3,530	Atlas
Miners Friend No. 2	B	do.	do.	166	7/8	242	10,330	3,150	do.
Miners Friend No. 4, L. F.	B	do.	do.	166	7/8	249	9,970	3,040	do.
Miners Friend No. 5, L. F.	B	do.	do.	166	7/8	250	8,560	2,610	do.
Miners Friend No. 6, L. F.	B	do.	do.	166	7/8	224	10,890	3,320	do.
Monobel No. 1, L. F.	A	do.	do.	176	7/8	231	12,860	3,920	du Pont
Monobel No. 2, L. F.	A	do.	do.	175	7/8	252	10,760	3,280	do.
Monobel No. 4, L. F.	A	do.	do.	175	7/8	252	10,760	3,280	do.
Monobel No. 5, L. F.	A	do.	do.	170	7/8	249	6,400	1,950	do.

---

[5] Same as Gelite 1 L. F.

1	2	3	4	5	6	7	8		9
				Grams	Inches	Grams	Ft. per second	Meters per sec.	
Monobel No. 6, L. F.	A	la	No. 6	176	7/8	220	13,610	4,150	du Pont
Monobel No. 8, L. F.	A	do.	do.	169	7/8	217	8,230	2,510	do.
Monobel No. 9, L. F.	A	do.	do.	134	7/8	223	6,330	1,930	do.
Monobel No. 10, L. F.	B	do.	do.	124	7/8	248	8,070	2,460	do.
Peerless No. 1	B	do.	do.	148	7/8	217	11,050	3,370	Peerless
Peerless No. 2	A	do.	do.	164	7/8	212	8,400	2,560	do.
Peerless No. 4	A	do.	do.	152	1-1/8	220	6,560	2,000	do.
Peerless No. 6	A	do.	do.	153	1-1/8	222	6,530	1,990	do.
Red H B, L. F.	A	do.	do.	155	7/8	213	12,140	3,700	Hercules
Red H C, L. F.	A	do.	do.	168	7/8	216	5,870	1,790	do.
Red H D, L. F.	A	do.	do.	150	7/8	214	7,740	2,360	do.
Red H F, L. F.	A	do.	do.	130	1	210	7,450	2,270	do.
Red H J, L. F.	A	do.	do.	164	7/8	209	7,540	2,300	do.
Red H No. 1	B	do.	do.	167	1-1/4	216	11,710	3,570	do.
Red H No. 4	B	do.	do.	164	7/8	248	8,990	2,740	do.
Red H No. 4-A, L. F.	B	do.	do.	170	7/8	227	9,350	2,850	do.
Red H No. 5	B	do.	do.	170	1	267	6,760	2,060	do.
Red H No. 6	B	do.	do.	162	7/8	218	10,360	3,160	do.
Red H No. 11	B	do.	do.	151	7/8	210	11,090	3,380	do.
Red H No. 14	B	do.	do.	151	7/8	236	10,460	3,190	do.
Tristate Special No. 1	B	do.	do.	130	1-1/8	223	7,050	2,150	Union
Tristate Special No. 2	B	do.	do.	136	1-1/8	236	8,920	2,720	do.
Trojan Coal Powder J	A	3	do.	229	1-1/4	360	10,590	3,230	Trojan
Trojan Coal Powder M-1	A	do.	do.	188	1	232	10,590	3,230	do.
Trojan Coal Powder M-2	A	do.	do.	178	1	232	10,660	3,250	do.
Trojan Coal Powder M-3	A	do.	do.	184	1	229	12,000	3,660	do.
Trojan Coal Powder M-4	A	do.	do.	180	1	212	12,270	3,740	do.
Trojan Coal Powder M-5	A	do.	do.	188	1	230	12,790	3,900	do.
Trojan Coal Powder M-6	A	do.	do.	190	1	242	11,810	3,600	do.
Trojan Coal Powder P-1	B	do.	do.	154	1-1/4	224	9,380	2,860	do.
Trojan Coal Powder P-2	B	do.	do.	174	1	226	12,890	3,930	do.
Trojan Coal Powder P-3	B	do.	do.	176	1	230	13,280	4,050	do.
Tunnelite C	A	la	do.	187	1-1/8	255	10,070	3,070	Atlas
Union A, L. F.	B	do.	do.	165	1-1/8	214	11,680	3,560	Union
Union B, L. F.	B	do.	do.	162	1-1/8	248	10,270	3,130	do.
Union D, L. F.	A	do.	do.	163	7/8	223	11,090	3,380	do.

1	2	3	4	5	6	7	8		9
				Grams	Inches	Grams	Ft.per second	Meters per sec.	
Union F, L. F.	B	1a	No. 6	142	1-1/8	207	8,460	2,580	Union
Union G, L. F.	A	do.	do.	162	1-1/8	237	6,760	2,060	do.
Union H, L. F.	B	do.	do.	147	1-1/8	217	8,430	2,570	do.
Vigorite No. 5, L. F.	C	4	do.	165	7/8	304	10,820	3,300	Atlas-Giant
Vulcan Coal Powder No. 1	C	do.	do.	160	1-1/4	335	7,810	2,380	Puget
Vulcan Coal Powder No. 2	B	do.	do.	164	7/8	283	10,660	3,250	do.
Xpdite No. 1	C	do.	do.	211	1-1/4	259	10,960	3,340	Hercules

Serial No. 2819
July, 1927

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

APPARATUS FOR VACUUM DISTILLATION OF LUBRICATING AND HEAVY PETROLEUM OILS.

By Martin J. Gavin[1] and Arch. L. Foster[2].

During the present study of lubricating oils in the San Francisco laboratory of the Bureau of Mines it became desirable to distill oils used in the experimental work at pressures as low as 10 mm., (mercury column) absolute. In the effort to overcome difficulties and eliminate sources of error the apparatus described below was finally developed.

The distilling flask is essentially the Hempel flask used by the Bureau of Mines for the analytical distillation of petroleum[3]. The complete apparatus is shown in Figure 1. As air leakage at connections is an ever present or potential source of difficulty and error in vacuum apparatus, the mouth of the flask is drawn down to one cm. internal diameter which materially simplifies obtaining an air-tight seal at this point. Before reducing the mouth, the spray screen is inserted and adjusted in position.

This screen is made of copper or brass gauze of 10 to 14 mesh, brazed or silver-soldered to a copper or brass tube of 4 or 5 mm. internal diameter. It is essential that the mesh of this screen be not too close or a column of oil will build up above it and eventually spatter over into the delivery tube and make an accurate distillation impossible. It is also important that the gauze have sufficient strength and rigidity to support the screen against the strains put upon it in charging, cleaning, etc. The supporting tube permits the introduction of small bits of broken Tonteller (boiling stone) into the charge of oil. After the screen is inserted into the neck of the flask it is conveniently held in place by heating small points on the neck wall with a blast flame and forcing the glass inward with a sharp point. Three or four points so placed at intervals just above and below the upper and lower screens respectively will suffice to retain the screen in position.

Even with fresh Tonteller placed in the flask before each distillation there was much trouble from bumping when heavy oils were distilled at 10 mm.

---

[1] Refinery engineer, Bureau of Mines, Department of Commerce.
[2] Associate petroleum chemist, Bureau of Mines.
[3] E. W. Dean and others: Analytical Distillation of Petroleum, Bureau of Mines Bull. 207, pp. 10-23.

Observation showed that the explosive vaporization in the overheated bottom layer of oil was coincident with the fall of the condensed droplet which collected at the discharge end of the side neck and plugged the vapor line until the drop fell of its own weight. This permits a slight building up of pressure in the flask and when the drop falls and opens the line, the sudden release of this increment of pressure permits the vaporization to occur at such a rate as to approach the proportions of an explosion, throwing liquid oil up through the screen and over into the delivery tube, vitiating the results of the determination.

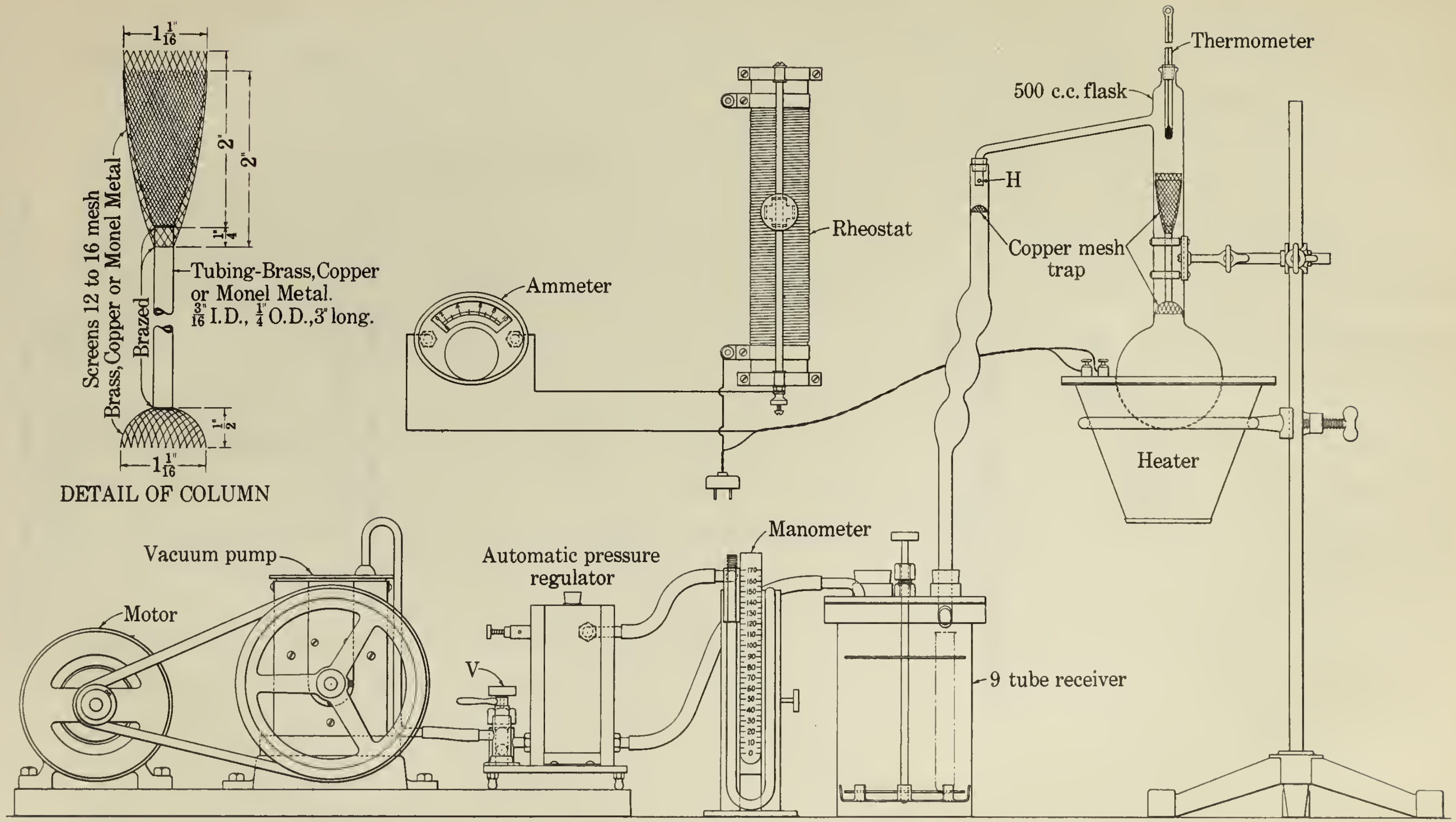
To eliminate this trouble two 1/16-inch holes were blown in the end of the delivery tube, 1/4 inch above the lowest extremity, as shown in Figure 1(H); this permits drops to form and fall into the condenser and at the same time prevents the slight fluctuation in pressure within the flask which causes the bumping. Under this arrangement, the distillation proceeds as smoothly as at atmospheric pressure.

Condenser and receiver are those described in Bureau of Mines Bulletin No. 207, the receiver holding nine graduated test tubes for collecting the various fractions.

To increase condenser efficiency a small gauze screen is inserted, convex side up, in the condenser just below the delivery tube; this distributes the hot condensate evenly over the condenser wall, allows it to cool to a lower temperature before it reaches the receiver and decreases or eliminates the volume correction to be applied to the distillate fractions for contraction on cooling in the receiver tube.

The pump used by the writers is a regular Cenco Hy-Vac. Pumps of this general type have ample capacity and if the system is carefully sealed, distillations may be carried out with ease at 1 mm. or lower.

The distillation procedure is as follows: small pieces of Tonteller are dropped into the flask through the open tube of the screen, the desired quantity of oil is poured into the flask, through a long funnel; a distillation thermometer with tight fitting cork is adjusted in the mouth of the flask and the delivery tube connected to the condenser by a snug cork. If necessary the joints are luted with litharge-glycerin paste and the pump started. When the pressure has been reduced to the desired degree as indicated by the closed manometer the valve, v, is partly closed and by trial adjusted so that the pressure is constant: the heating is started, the oil brought to distilling temperature very gradually with steadily increasing heat, and the slide wire rheostat so regulated that the oil distills at a rate of 3 to 5 cc. per minute. Some manipulation of the control valve, v, is necessary to adjust the pressure after the system is in full operation but once adjusted it requires remarkably little attention to regulate within very narrow limits. Ordinarily the automatic pressure regulator is not used, as manual control of pressure is quite satisfactory. If the regulator is not used it is advisable to have a reservoir of at least one liter capacity in the suction line between valve "v" and receiver to smooth out minor pressure fluctuations.


Thermometer
500 c.c. flask
H
Copper mesh trap
Rheostat
Ammeter
Heater
Manometer
9 tube receiver
Automatic pressure regulator
V
Vacuum pump
Motor
$1\frac{1}{16}''$
$2''$
$2''$
$\frac{1}{4}''$
Screens 12 to 16 mesh
Brass, Copper or Monel Metal
Tubing-Brass, Copper or Monel Metal. $\frac{3}{16}''$ I.D., $\frac{1}{4}''$ O.D., 3" long.
Brazed
$\frac{1}{2}''$
$1\frac{1}{16}''$
DETAIL OF COLUMN

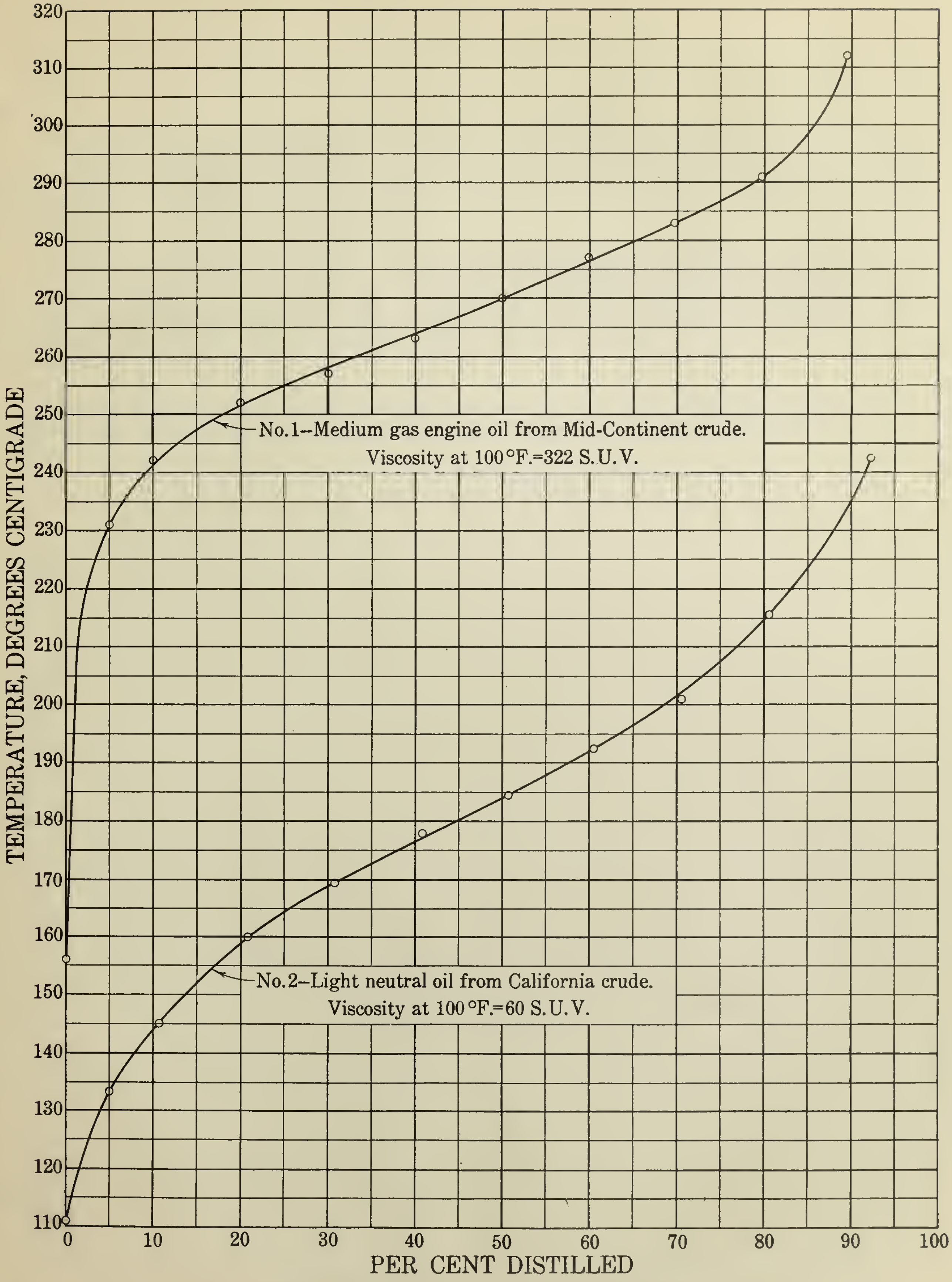


FIGURE 2–Distillation curves for two lubricating oils

By this apparatus and method it is a comparatively simple matter to obtain clean-cut distillations, the data on which are accurate, comparable, and reproducible. Vapor temperatures, especially, are more reliable and reproducible than with any other method so far attempted.

Examples of data obtained, using this apparatus, are shown in Table 1. Nos. 1, 3, 5, and 7 are distillations on medium internal combustion engine oils made from the various crudes as noted, while Nos. 2, 4, 6 and 8 show results on these oils after being used in experimental engine runs in the San Francisco laboratory.

Table 2 also gives distillation results on two oils varying widely in volatility and viscosity, and curves from this data are shown in Figure 2.

Table 1--Showing results of vacuum distillations of lubricating oils from various crudes.

MEDIUM INTERNAL COMBUSTION ENGINE OILS - from

Cut No.	MID-CONTINENT CRUDE						GULF COASTAL CRUDE					
	(1) New			(2) Used			(3) New			(4) Used		
	Vol. c.c.	Dist. per cent	Temp. °C.	Vol. c.c.	Dist. per cent	Temp. °C	Vol. c.c.	Dist. per cent	Temp. °C	Vol. c.c.	Dist. per cent	Temp. °C
over	0.0	0.0	156.0	0.0	0.0	150.5	0.0	0.0	142.0	0.0	0.0	135.0
-	3.0	1.2	205.0	3.0	1.2	208.5	3.0	1.2	179.0	3.0	1.2	176.0
-	6.0	2.4	220.5	6.0	2.4	224.5	6.0	2.4	186.0	6.0	2.4	188.0
-	9.0	3.6	227.0	9.0	3.6	231.0	9.0	3.6	190.0	9.0	3.6	200.5
1	25.0	10.0	242.0	26.7	10.7	243.8	25.4	10.1	201.5	28.0	11.2	214.0
2	50.0	20.0	252.0	51.6	20.7-	254.0	51.6	20.6	214.5	53.6	21.4	220.5
3	75.6	30.0+	257.0	76.6	30.6	262.2	76.0	30.4	221.5	79.0	31.6	233.5
4	100.0	40.0	263.0	100.9	40.70	268.5	101.2	40.5	228.0	104.4	41.7	242.5
5	125.0	50.0	270.0	125.6	50.3	277.2	126.8	50.7	235.0	129.4	51.8	251.0
6	149.8	60.0	277.0	155.1	62.1	286.0	152.2	60.9	245.0	154.8	61.9	257.5
7	174.4	69.7	283.0	179.5	71.8	293.5	177.4	71.1	252.0	182.2	72.9	265.5
8	199.2	79.6	291.0	202.0	80.9	305.5	204.4	81.8	265.0	207.2	83.0	276.5
9	223.4	89.4	312.0	222.6	89.0	320.5	227.6	91.1	277.0	226.2	90.5	284.0

Cut No.	CALIFORNIA CRUDE						PENNSYLVANIA CRUDE					
	(5) New			(6) Used			(7) New			(8) Used		
over	0.0	0.0	162.0	0.0	0.0	152.0	0.0	0.0	210.0	0.0	0.0	160.0
-	3.0	1.2	173.0	3.0	1.2	175.0	3.0	1.2	216.0	3.0	1.2	201.0
-	6.0	2.4	177.0	6.0	2.4	182.0	6.0	2.4	221.0	6.0	2.4	225.0
-	9.0	3.6	180.5	9.0	3.6	185.0	9.0	3.6	224.0	9.0	3.6	228.0
1	25.4	10.1	193.0	25.0	10.0	198.5	25.0	10.0	231.0	25.2	10.1	235.5
2	50.8	20.3	210.0	50.0	20.0	214.0	50.0	20.0	241.0	50.2	20.1	248.0
3	76.0	30.4	220.5	75.0	30.0	226.0	75.0	30.0	248.0	75.0	30.0	254.0
4	101.0	40.4	229.5	105.0	42.0	236.0	99.8	39.9	254.0	100.0	40.0	261.0
5	126.2	50.5	241.0	131.4	52.5	248.0	125.2	40.1	262.0	125.0	50.0	268.0
6	151.4	60.6	252.0	152.0	60.8	254.0	151.6	60.7	271.0	149.4	59.7	276.0
7	178.4	71.4	266.5	174.0	69.6	268.5	176.2	70.5	278.0	174.4	69.7	285.5
8	207.4	83.0	280.5	196.4	78.6	276.5	201.8	80.7	292.0	200.2	80.1	296.5
9	227.8	91.0	295.0	222.4	89.0	296.0	225.8	90.3	311.0	225.0	90.0	314.5

Table 2--Showing differences in volatility and viscosity between two new oils.

	No. 1			No. 2		
Cut	Temp.	Vol. Distilled		Temp.	Vol. Distilled	
No.	°C	c.c.	per cent	°C	c.c.	per cent
over	156.0	0.0	0.00	111.0	0.0	0.0
1/2	231.0	12.5	5.00	133.5	12.5	5.0
1	242.0	25.0	10.00	145.0	26.8	10.72
2	252.0	50.0	20.00	160.0	52.2	20.88
3	257.0	75.6	30.02	169.5	77.2	30.88
4	263.0	100.0	40.00	178.0	102.0	40.80
5	270.0	125.0	50.00	184.5	126.8	50.72
6	277.0	149.8	59.98	192.5	151.4	60.56
7	283.0	174.4	69.75	201.0	176.4	70.56
8	291.0	199.2	79.70	215.5	201.4	80.56
9	312.0	223.4	89.40	242.0	230.4	92.16

Reports of Investigations, Bureau of Mines, Department of Commerce.

[illegible] GEOLOGICAL [illegible]

Serial No. 2820.
July, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

THE WIRE SAW IN SLATE QUARRYING.

PRELIMINARY REPORT

By Oliver Bowles[1]

Introduction

Slate possesses many admirable qualities, not only as a roofing material, but for blackboards, electrical switch boards, and for various structural uses such as stair treads, floor tile, baseboards, and sanitary enclosures. The American slate industry was established many years ago, and has made remarkable progress, particularly during the past five years. One of the chief drawbacks to more rapid expansion is the high percentage of waste which reaches 75 to 94 per cent of gross production. Much of this waste is due to rock imperfections over which man has no control, but a careful study of the industry by the Bureau of Mines over a period of years indicates that an undesirably large percentage of the marketable slate is wasted in the processes of quarrying and manufacture.

The initial step in quarrying slate is to separate from the solid ledge masses of a size that may be conveniently removed from the quarry. This first step entails a greater waste of material than any subsequent process, and, therefore, invites the most earnest effort toward waste reduction. Attention has consequently been directed toward possible improvements in methods of making primary cuts in the quarry floor. A study of European practice with the wire saw, together with theoretical consideration of its advantages, convinced the writer that it possessed sufficient merit to justify its use as a primary slate cutter in American quarries. No practical conclusion in this matter could be reached except by experiment. Therefore, the desirability of obtaining equipment and trying it out under actual conditions of operation was urged upon operators. While no doubt the equipment could be readily manufactured in America, it had already been developed to the point of practical use in Europe; therefore the writer urged the desirability of purchasing one completely equipped wire saw in Europe, and determining through tests whether it gave sufficient promise of success to warrant its manufacture in America.

In collaboration with W. S. Hays, Secretary of the National Slate Association, it was arranged that five Pennsylvania slate companies would cooperate with the

---

[1] Superintendent, Nonmetallic Minerals Experiment Station, New Brunswick, New Jersey. (In cooperation with Rutgers University).

Nonmetallic Minerals Experiment Station of the bureau in purchasing the equipment. The following took part in this enterprise; R. S. Whitesell, of the Hard Vein Slate Co., Arch Jones, of the Amalgamated Slate Quarries, Harry Stoddard, of D. Stoddard & Sons, William Blake, of the Columbia Bangor Slate Co., and Clarence Doney, of the Doney Slate Co. An order was placed with a Belgian firm and delivery was made late in 1926. The bureau employed the temporary services of J. R. Thoenen, a mining engineer of wide experience. The machine was assembled and put in operation under his direction at the Colonial Slate Co. quarry near Wind Gap, Pennsylvania. The writer desires to express his appreciation of the cordial cooperation of Sidney Spry, president of the above company, in conducting the tests and in working out improvements in the design of the machine.

The Wire Saw.

The wire saw consists of a three-strand steel cable, slightly more than 3/16 inch in diameter, running as an endless belt. The wires used in the tests recently made were between 600 and 900 feet long. The wire belt is driven by a $7\frac{1}{2}$ hp.-motor through belt and counter-shaft to give the desired speed reduction. The driving pulley is a double-grooved cast-iron sheave 40 inches in diameter. A special device provides the desired tension. A weight of 800 to 1000 pounds was found necessary in these experiments. Orienting pulleys 28 inches in diameter are provided for conducting the wire from the driving mechanism to the sheaves at the ends of the cut in the quarry. The pulleys may be adjusted radially, and a ball-and-socket joint permits orientation to suit the position of the cut. At each end of the saw cut a steel I-beam standard is provided as support for the saw guide sheave. The lower sheaves which guide the wire as it enters and leaves the cut may be raised or lowered on the standards.

The wire saw when in operation passes from the standard at one end of the cut through the slate to the second standard, thence to the drive mechanism and back to the first standard. Sand and water are fed to the saw and drawn through the cut by it. The wire travels at the rate of 14.3 feet per second.

The arrangement of the equipment is shown diagramatically in fig. 1. The wire a passes over the orienting pulley b to the guide pulley c, through the cut to the guide pulley d, the orienting pulley e and from thence to other orienting pulleys and to the driving mechanism on the quarry bank. The guide pulleys c and d are fed downward by worm gear to maintain pressure of the wire on the rock as the cut is worked downward. Sand is fed to the wire from V-shaped boxes. It is carried into the cut by a small stream of water from rubber hose connected with a pipe line, and entering the upper end of the sand box. Three boxes were used in the tests conducted, one being placed as close as possible to the point where the wire enters the rock. It was found by experiment that the stream of water should not be reduced too greatly, it should occupy one-third to one-half the opening of a 3/4 inch rubber hose. If insufficient water is supplied the sand rides on the wire while a larger stream carries it beneath the wire where the effective cutting takes place. A sharp silica sand free from pebbles is desirable. If pebbles are abundant they gradually fill the cut and make it difficult to supply sand to the wire.

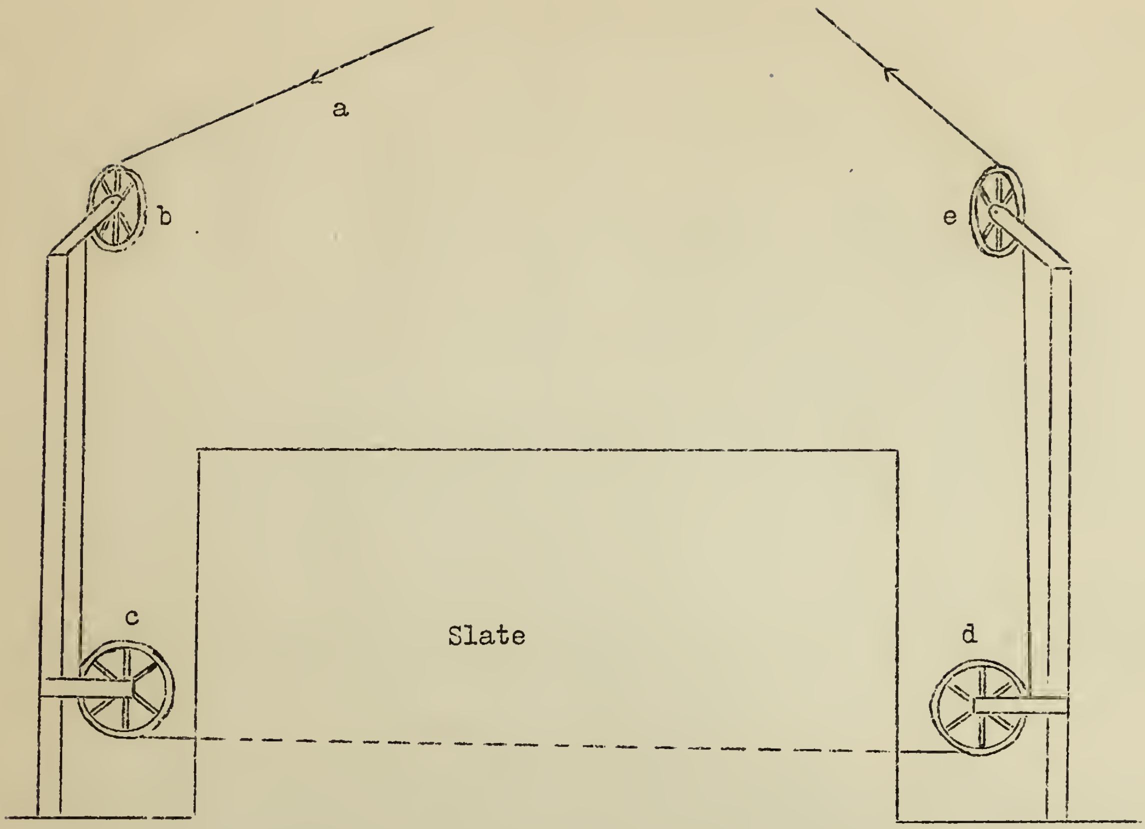


FIG. 1 - ESSENTIAL PARTS OF WIRE SAW EQUIPMENT, (a) WIRE, (b)(e) ORIENTING PULLEYS, (c)(d) GUIDE PULLEYS.

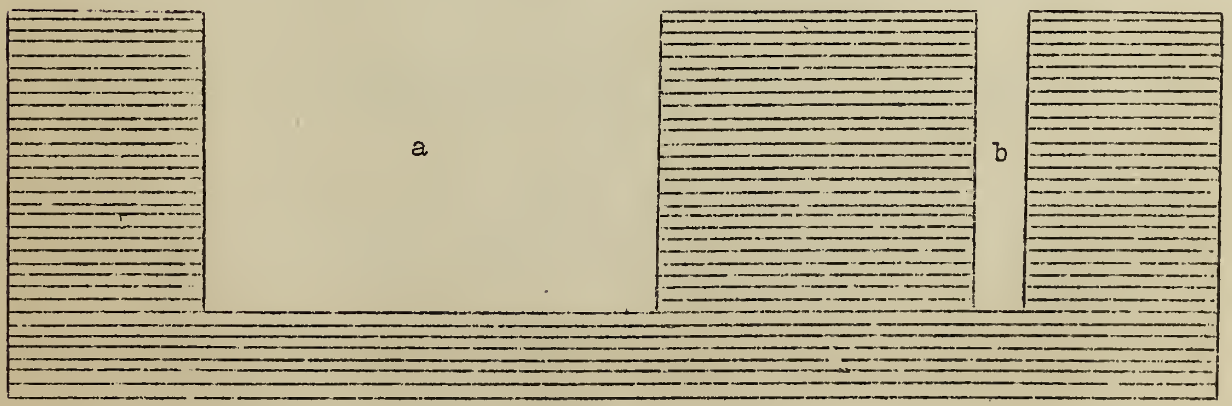


FIG. 2 - ACTUAL WIDTH OF CHANNEL CUT COMPARED WITH WIRE SAW CUT. (a) CHANNEL CUT 2-3/8 INCHES, (b) WIRE SAW CUT 1/4 INCH.

It is obvious from fig. 1 that holes or open benches must be provided in order that the movable guide pulleys may descend as the cut progresses. Where open benches are not present apparatus must be provided for sinking holes in the rock. The standard equipment for this purpose as purchased in Belgium consists of a welded steel drum 6 ft. long and 36 in. in diameter with metal teeth on its lower edge. It is driven at the rate of 70 r.p.m. with a 15 hp.-motor, and as sand and water are fed to it, it cuts out a drum or core. When this core is removed a hole of sufficient size is provided for the standard and the lower 28-inch sheave. For most of the cuts recorded herein the wire was run at an angle in order to conform with the inclined slaty cleavage, therefore the wire ran out at the surface at the upper end of the cut, and no standard hole was required. Also as noted hereafter two nearly parallel cuts were made about 5 feet apart, and the slate between them removed. This provided a trench or channel in which the standard was placed for making cuts in a direction at right angles to the trench.

The drum drill is not entirely satisfactory. Another type of equipment for sinking holes is being tried out, and will be reported upon later. The sinking of holes for the standards is the most difficult part of the entire operation.

The Channeling Machine.

The present method of making wall cuts, and certain other cuts, as for example, in opening up a new bench, is by means of a channeling machine operated on a track. The channeling machine costs approximately $5000, requires 2 men to operate it, and cuts on an average about 50 square feet of surface per day. It is a standard type of equipment in quarrying slate, marble, limestone and sandstone, but, as used in slate, it has serious limitations and disadvantages. Not only is it costly to purchase and expensive to operate, but, as it cuts by reciprocal motion in the same manner as a piston drill, the heavy blows of the steel shatter or "stun" the slate for a distance of one to two feet on either side of the cut, thus causing excessive waste. The wire saw on the other hand cuts by a process of steady abrasion, and therefore causes no shattering.

Comparison of Cuts Made with Channeling Machine and Wire Saw.

It was found by actual measurement that a channel cut 8 ft. deep in a Pennsylvania quarry is 3 inches wide at the top and 1$\frac{3}{4}$ in. wide at the bottom, thus having an average width of 2 3/8 in. The wire saw cut is $\frac{1}{4}$ inch wide.

The process of procuring a cut is essentially the chopping, pulverizing or abrading and subsequent removal of the slate occupying the space of the cut. It is obvious from the above figures, and is indicated graphically in figure 2, that more than 9 times as much material must be cut and removed by the channeling machine as by the wire saw in order to make a cut of the same surfade area in each case. No data are now available on the relative amount of energy expended by the chopping method of the channeling machine as compared with the abrasive method of the wire saw. Assuming, however, that they are equally efficient more than 9 times as much work is expended in making the channel cut as in making the wire saw cut. Furthermore, the channeling machine expends additional energy in shattering the slate adjacent to the cut, energy which is worse than wasted in that it is destructive.

Theoretically, therefore, the wire saw should be much more economical than the channeler. Several factors contribute to the economy; (1) the power requirement is much lower, (2) the first cost is less than one-fourth that of a channeler, (3) the labor requirement is about one-half that of a channeler, (4) the cutting is more rapid and continuous, and (5) the proportion of waste rock is greatly reduced. In order to test the soundness of the theoretical conclusions a series of tests were made, the results of which are given in the following pages.

Tests Made Under Direction of Bureau of Mines.

Records were maintained for five wire-saw cuts made in the Colonial Slate Company quarry. The diagram, fig. 3, shows the relative positions of the various cuts. The figures in parenthesis are the numbers assigned to the cuts as described in the following pages.

Cut No. 1. The drum drill was employed to make a hole for one standard, the other standard being placed on an open bench. For a hole 6½ ft. deep a total of 13 hours 12 minutes drilling time was required. The slate was in broken condition in consequence of which many fragments slipped into the cut and were ground up by the drum. It was estimated that the drill operated in solid slate for 10 hours 25 minutes. The average depth drilled per hour was 6½ inches, and the maximum rate attained was 10 inches per hour. The abrasive employed was a sea sand, 96 per cent of which would pass through a 20-mesh screen.

When the hole was completed and the core removed, the standards were placed and a 670-foot wire cable mounted on the sheaves. To make an endless belt the wire must be spliced, an operation which demands great care, for the splice must be smooth and even. Any projecting part will wear excessively, and will also tend to bind in the cut. The wire saw was in operation parts of three days on a cut 72 ft. long. A sea sand similar to that used with the drill was employed as abrasive. The measure of accomplishment is the surface area of the cut made, thus a cut 80 ft. long and 10 ft. deep would have a surface area of 800 square feet.

The following results were obtained:

Total cutting time	8½ hours
Total square feet cut	82.4
Average square feet per hour	9.7

Postponement of Tests. The above test was run in December, 1926, under unfavorable weather conditions. Further testing was suspended until spring, in consequence of which cut No. 1 was not completed. Cuts 2, 3, 4 and 5 were made during April and May, 1927. Unfortunately the services of J. R. Thoenen were not available for these tests. The work was done under the general supervision of Sidney Spry, president of the Colonial Slate Company, and under the immediate direction of Floyd Wideman, an employee of the above company.

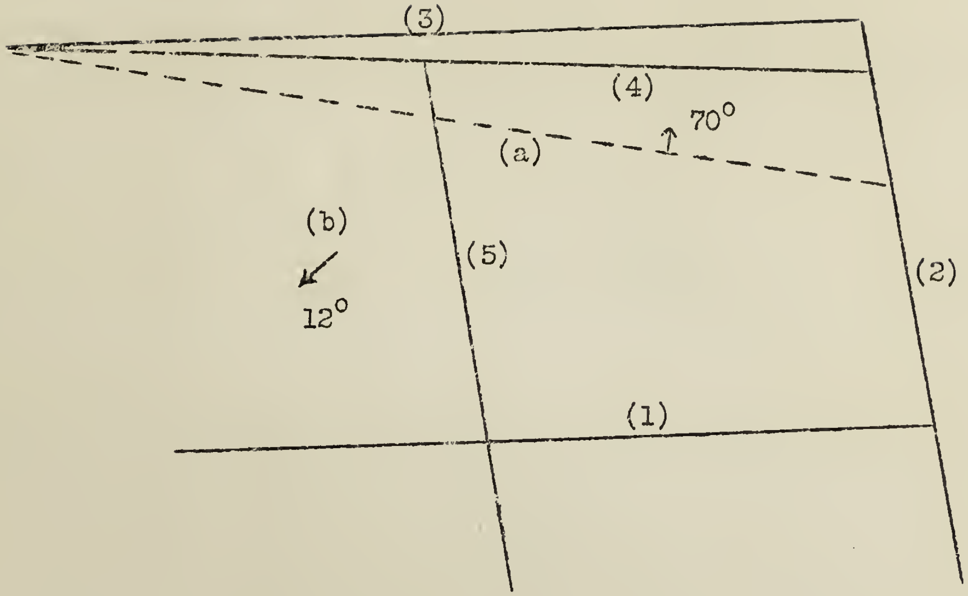
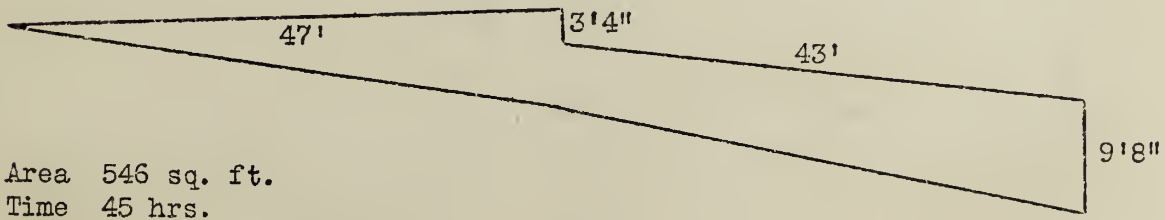
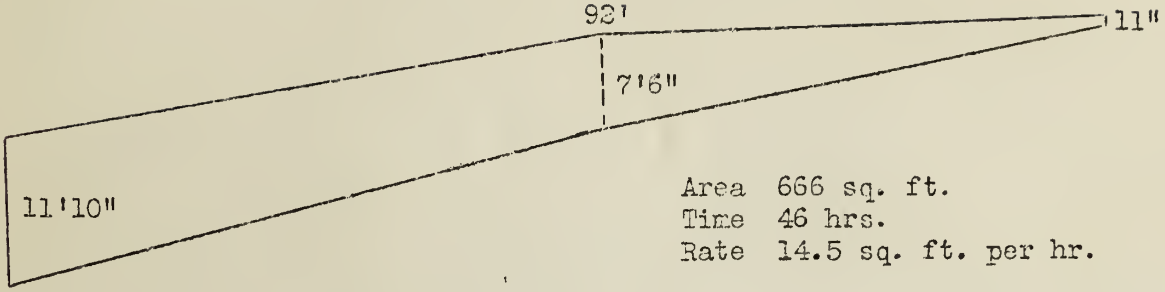


FIG. 3 - PLAN SHOWING RELATIVE POSITIONS OF EXPERIMENTAL CUTS. (a) DIRECTION OF RIBBON. (b) DIP OF SLATY CLEAVAGE.



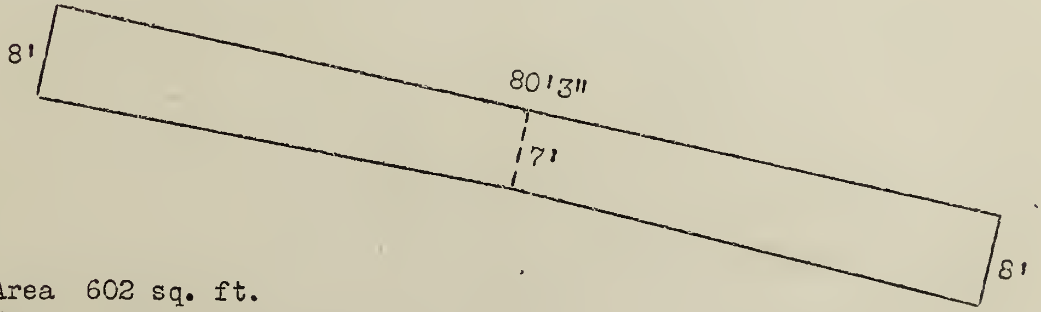
Area 546 sq. ft.
Time 45 hrs.
Rate 12.1 sq. ft. per hr.

FIG. 4 - VERTICAL SECTION SHOWING CUT NO. 2. SCALE: 1/16 INCH = 1 FT.



Area 666 sq. ft.
Time 46 hrs.
Rate 14.5 sq. ft. per hr.

FIG. 5 - VERTICAL SECTION SHOWING CUT NO. 3. SCALE: 1/16 INCH = 1 FT.



Area 602 sq. ft.
Time 47 hrs.
Rate 12.8 sq. ft. per hr.

FIG. 6 - VERTICAL SECTION SHOWING CUT NO. 5. SCALE: 1/16 INCH = 1 FT.

Cut No. 2. For cut No. 2, as shown in fig. 4, one standard was much lower than the other in order to conform with the "split" or slaty cleavage of the rock, which in the direction of this cut dips about 13°. The lower standard was placed at an open bench, and as the wire ran out at the surface at the upper end no standard holes were required. Setting up the equipment ready to operate occupied 2 men for 2 days. A wire approximately 700 feet long was used.

The record of the cut follows:

Length of cut on rock surface	90 ft.
Total area cut	546 sq. ft.
Total cutting time	45 hrs.
Rate per hour	12.1 sq. ft.
Average cutting rate per 9 hr. day	109 sq. ft.

As indicated in figure 3, the cut crossed the ribbon (a) nearly at right angles.

Cut No. 3. As indicated in the diagram (fig. 3), cut No. 3 was made in a direction almost at right angles to cut No. 2, thus intersecting the ribbon at a long angle. The wire was inclined about 11° to conform with the slaty cleavage. A standard hole was cut in the corner of the quarry at the upper end of the cut, but on account of the inclination of the wire the completed cut reached a point only 11 in. downward from the top of the hole. Putting down a standard hole 6½ ft. deep with the drum drill required the time of one man for 5 days and a second man for 4 days 2 hours. The lower standard was placed on an open bench. A wire about 750 ft. long was used. Following is the record of cut No. 3, which is shown diagramatically in fig. 5:

Length of cut on rock surface	92 ft.
Maximum depth of cut	11 ft. 10 in.
Total surface area	666 sq. ft.
Total cutting time	46 hrs.
Rate per hour	14.5 sq. ft.
Average rate per 9 hour day	130.5 sq. ft.

Cut No. 4. Cut No. 4 was made nearly parallel with No. 3, being about 6 inches distant from it at the lower end and 5 feet distant at the upper end. The purpose was to cut off a mass which when removed would leave a channel or trench in which the standard might be placed for cuts at right angles. Cut No. 5, described later was made with the upper standard in this trench. The purpose in cutting out a wedge-shaped mass was to facilitate removal of material, for the wire saw cut, being only one-fourth inch wide, gives so little space that the masses of slate would jam and cause loss of time in their removal if the cuts were parallel. Placing equipment for this cut occupied the equivalent of 7 hours time for one man.

Cut No. 4 suffered more interruption than previous cuts. An attempt was made to use the wire that made cut No. 3, in order to determine how completely a wire could be worn and still give service. Difficulty was first experienced in getting a smooth splice, and cutting had to be suspended to correct the splice. The old wire was run for 16 hours and then abandoned and a new wire substituted. The worn wire was found to be so smooth that it failed to carry the sand properly, and the cutting rate was very slow. This experience was valuable for it indicated that difficulty and loss of time will result if an attempt is made to use a wire that has already served to make a cut. The cost of the wire is so small that it is undoubtedly more economical to begin every cut with a new wire. It is noteworthy also that no difficulty is experienced in introducing a new wire in the partly completed cut. On account of the slow progress with the old wire a total of 55 hours cutting time was required. The cut is practically identical with Cut No. 3, and the record is as follows:

Total surface area	666 square feet
Total cutting time	55 hours
Rate per hour	12.1 sq. ft.

The total time devoted to this cut including set up and all interruptions was 10 days, giving an average of 66.6 sq. ft. per day total time.

Cut No. 5. As indicated in the diagram (fig. 6), in making this cut one of the standards was placed in the trench formed by removal of the rock between cuts 3 and 4. The other standard was placed at an open bench. The cut was 80 ft. 3 in. long and 8 ft. deep. For this cut wire purchased from an American firm, the Waterbury Co., was used in place of the Belgian wire. It is the same diameter as the latter, but is more closely wound, each strand making a complete turn in one inch whereas in the Belgian wire one turn occupies 1 1/8 inches. The American wire apparently gives just as good service as the Belgian wire. A wire approximately 700 feet long was used. Placing the standards, threading and splicing the wire ready to begin work required 8 hours time for one man. It is noteworthy that as experience is gained the time required for setting up is reduced. The following results were obtained:

Total surface area	602 sq. ft.
Total cutting time	47 hours
Rate per hour	12.8 sq. ft.

Thus for the 4 cuts recorded above made in April and May a total of 2480 sq. ft. of surface was obtained in 193 hours running time, or an average of 12.8 sq. ft. per hour.

Cost of Wire Saw Operation.

From the results of the above tests as complete data as possible have been compiled to determine the actual cost of operating the wire saw. The work done in December, 1926, being incomplete, is omitted. The costs are tabulated as follows:

Labor:	
Putting down drill hole	
1 man 5 days at $6. per day	$30.00
1 man 4 days 2 hrs. at $6. per day	25.33
Placing Wire Saw	
Cut No. 2	
1 man 2 days at $6. per day	12.00
1 man ½ day at $6. per day	3.00
Cut No. 3	
1 man 2 days 5 hrs. at $6. per day	15.33
1 man 5 hrs. at $6. per day	3.33
Cut No. 4	
1 man 7 hrs. at $6. per day	4.67
Cut No. 5	
1 man 8 hrs. at $6. per day	5.33
Sawing	
Cut No. 2	
1 man 5 days at $6. per day	30.00
Cut No. 3	
1 man 5 days 1 hr. at $6. per day	30.67
Cut No. 4	
1 man 9 days 2 hrs. at $6. per day	55.33
Cut No. 5	
1 man 5 days 2 hrs. at $6. per day	31.33
Power:	
Drum drill, 15 hp. 11.2 kw.x 13 hrs. = 146 kwh. at 2 cents	2.92
Wire saw, 7½ hp. 5.6 kw. x 193 hrs. = 1081 kwh. at 2 cents	21.62
Sand:	
10 tons at $2.80	28.00
Wire:	
2900 ft. at 9/10 cents per ft.	26.10
Oil, water and other incidentals (est.)	25.00
Amortization and repairs (est.)	50.00
Interest on investment, $1400 at 6% for 1 2/3 mo.	11.67
Total	411.63

Total area cut, 2480 sq. ft. Cost 16.6 cents per sq. ft.

It is estimated that a channeling machine cuts an average of 50 sq. ft. per day, and that the total operating cost, including labor, supplies, power, repairs, interest and amortization is approximately $20. per day. Thus the channeling machine cost is about 40 cents per square foot, or about 2½ times as much as the cost of cutting with the wire saw.

It may be noted in the above calculation that only one standard hole was drilled, although 4 cuts were made, as three of the cuts ran out at the surface and no holes were needed. It is obvious that as the surface is worked down parallel with the "split" or slaty cleavage, more standard holes will be required for subsequent cuts, and therefore, the average cost may be somewhat higher than the figure obtained. However, it seemed advisable for this preliminary report to give the actual costs without attempting to recalculate them on any other basis.

Reduction in Waste by Use of Wire Saw.

In previous pages attention has been directed mainly to rate and cost of cutting. The wire saw offers decided advantages also in conservation of slate. The channeling machine, as mentioned previously, shatters the slate on either side of the cut. The quarry operator always tries to make his channel cuts in inferior beds, but frequently cuts must be made across the beds of highest quality, and much waste results. The wire saw cuts by steady abrasion, and thus causes no shattering. Blocks 30 inches long were taken from the wedge-shaped mass of slate between cuts 3 and 4, were sent to the splitting shanty, and split into roofing slate directly from one wire saw cut to the other. The smooth wire-cut surfaces are also of advantage to the splitter in the slate-making process.

Mill blocks with wire cut surfaces are found to be doubly advantageous. In the first place there is no necessity for removing 12 to 18 inches of shattered slate next to the cut surface, as is the case when channeling machines are used. Thus the waste is greatly reduced. In the second place the wire cut surface may constitute a face of the block, and the time and expense of an additional circular saw cut is saved.

Sufficient work has not yet been done to determine with any degree of accuracy the actual reduction in waste by use of the wire saw, but undoubtedly it conserves many cubic feet of good slate for every cut made.

It is planned that in future work in the quarry where the tests were made one set of wire saw cuts will follow a direction at right angles to the ribbon, and another set will be made to conform in direction and dip with the ribbon, possibly cutting in the ribbon itself. Thus the beds of clear stock would be preserved intact and the waste would be further reduced.

Other Advantages.

A great advantage of the wire saw is its simplicity and ease of operation. The only attention required consists in maintaining a supply of sand in the sand boxes, regulating the streams of water carrying the sand into the cut, and, at intervals of about every half hour, feeding the guide pulleys at either end of the cut downward a distance of ½ to 1½ inches depending on the length of the cut and the cutting rate. One man can easily perform these duties and with much time to spare. If it is desirable to run overtime, the equipment being motor driven requires the extra time of one man only. It would be quite feasible in fact to supervise the operation on the basis of three 8-hour shifts per day, and to run the wire night and day continuously until a cut were completed. On the basis of the average rate of cutting already attained about 300 sq. ft. of surface could be cut every 24 hours, that is, one wire saw operating continuously could do the work of 6 channeling machines working day shifts only.

Another advantage is the absence of equipment along the course of the cut. As there is no machinery or trackage in the way, slate blocks may be removed from points adjacent to the upper part of the cut while the wire is still in operation in the lower part of the cut. Such a course was followed during the recent tests without any detriment to the operation of the saw.

Another advantage is the ease with which cuts may be made at an angle to the vertical. By inclining the standards the wire may be made to cut at any desired angle. Thus undercutting of the walls is comparatively easy. Cuts may be made approaching a horizontal position provided there is sufficient inclination to carry sand and water to the wire.

Curvature of the Wire Saw Cut.

As the wire cuts in consequence of the downward thrust of the guide pulleys at either end, it is inevitable that in a cut 80 or 90 feet long the wire will arch upward in the middle, in other words when the cut is finished at the ends it will still be unfinished in the middle. The amount of this upward curvature has been the subject of considerable conjecture, some even going so far as to claim that the wire might be 5 feet higher in the center than at the ends of a long cut. If such were the case, wire saw operation could scarcely be regarded as a success. Careful attention has, therefore, been given to this phase of the problem. Measurements and observation of some of the cuts already made indicate that the centers are not more than 6 inches to one foot higher than the ends. The cutting down of the center to this extent is accomplished in two ways, first by maintaining a heavy tension, approximately 1000 pounds, on the wire; and second by running the wire for a period of 3 or 4 hours after the ends have reached bottom, thus cutting down the center and reducing the curvature.

Possible Disadvantages.

From observations made up to the present time only two possible disadvantages appear. First the saw cut is so narrow that difficulty may be experienced in removing blocks when a new bench is about to be opened up. A channel cut being about 2 inches wide gives considerable leeway, but, as the wire cut is only one-fourth inch wide, blocks may jam if proper precautions are not taken. If a wedge-shaped mass is first removed, as between cuts 3 and 4 shown in fig. 1, this difficulty may be overcome.

A second possible disadvantage is interference of the wire with other quarry operations. The wire passing from the driving mechanism on the bank over the quarry opening to the cut and back to the bank may cross the path of slate blocks and waste boxes as they are being hoisted and removed by means of the overhead cableways. Under such conditions hoisting must be conducted with great care to avoid interference with the wire. The wire saw may thus constitute a danger as well as a source of inconvenience. If the location of the driving mechanism and the course of the wire are worked out carefully the difficulty may be reduced to a minimum.

Summary.

1. Tests recently conducted under normal quarry conditions indicate that the wire saw will cut about twice as fast as the channeling machine, and at about two-fifths of the cost per square foot of surface obtained.

2. The first cost of wire saw equipment is about one-fourth that of a channeling machine.

3. Aside from some additional help in placing the equipment the wire saw requires only one man to operate it, whereas the channeling machine requires two men

4. As the wire saw makes a narrow cut and causes no shattering the proportion of waste is greatly reduced.

5. The wire cut surfaces offer advantages in splitting blocks into roofing slates, and in reducing the number of saw cuts in finishing mill stock.

6. The wire saw lends itself readily to overtime work.

7. The narrow wire saw cut may cause binding of blocks during their removal unless a wedge shaped mass is first removed.

8. The wire cable passing over the quarry may be a source of danger and inconvenience if proper precautions are not taken.

9. The most difficult part of the entire operation is the sinking of holes for the standards. Various methods are being tried out and the results of the tests will be given in a later report.

10. Recognition of the success of the wire saw is already in evidence as follows:

First, the Colonial Slate Company, at whose quarry the tests were made, has dismantled one channeling machine, and the machine runner is now learning to operate the wire saw.

Second, this company is purchasing for its own use complete wire saw equipment, part of which is already in operation.

Serial No. 2821.
July, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

COAL-MINE FATALITIES IN JUNE, 1927.

By W. W. Adams[1]

Accidents at coal mines in the United States in June 1927 caused the death of 156 men, according to information furnished by State mine officials to the Bureau of Mines, Department of Commerce. Forty-nine of the accidents were at the anthracite mines in Pennsylvania; the remaining 107 were at bituminous coal mines in various States. As the output of coal during the month was 43,884,000 tons, the fatality rate per million tons was 3.55, as compared with 3.36 in June a year ago. The rates for anthracite and bituminous mines separately were 6.75 for the former and 2.92 for the latter, the corresponding rates for June last year being 5.37 and 2.93, respectively. The production of coal during June included 36,627,000 tons of bituminous coal and 7,257,000 tons of anthracite.

Records covering accidents during the first half of 1927 show a loss of 1,162 lives, as against 1,191 during the corresponding months of 1926. These figures represent fatality rates of 3.66 and 3,92, respectively, per million tons of coal produced, thus indicating a reduction of 7 per cent in the frequency of fatal accidents during the present year. The fatality rate for bituminous mines alone was 3.23 per million tons, based on 894 accidents and a 6-months' production of 276,627,000 tons. The 6-months' fatality rate of 3.23 for bituminous mines indicates a reduction of 14 per cent from the death rate of 3.78 for the first six months of 1926. For anthracite mines alone the returns for the first half of 1927 showed 268 fatalities and indicated a fatality rate of 6.55 per million tons as compared with 4.96 for the corresponding period last year.

The month of June 1927 was free from major disasters, that is, accidents causing the death of five or more men. Thus far in 1927 seven major disasters have occurred with an aggregate loss of 140 lives. During the first half of 1926 there were eight major disasters resulting in 194 deaths. Fatality rates based exclusively on these disasters were 0.639 in 1926 and 0.441 in 1927, a reduction of 31 per cent in the present year.

A comparison of the principal causes of accidents during the first six months of 1927 with the corresponding record for 1926 shows that in 1927 the death rates have been lowered for falls of roof and coal, for haulage accidents, and for explosions of gas and dust. The rates for explosives and electricity are somewhat higher than the corresponding rates last year. Comparative rates per million tons are as follows:

---

[1] Statistician, Bureau of Mines, Department of Commerce.

	Year 1926	Jan.-June 1926	Jan.-June 1927
All causes	3.790	3.921	3.660
Falls of roof and coal	1.829	1.876	1.716
Haulage	.650	.658	.573
Gas or dust explosions:			
Local explosions	.111	.138	.148
Major explosions	.525	.639	.419
Explosives	.145	.129	.202
Electricity	.143	.122	.151

Tables 1 to 4, inclusive, present a detailed statistical comparison of the number of accidents and the accident rates in 1927 with similar figures for earlier periods. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE 1.- NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES

	Year 1926	Jan.-June 1926	Jan.-June 1927
Falls of Roof & Coal	1.829	1.876	1.716
At face	1.386	1.435	1.281
In room	.238	.244	.223
On entry	.193	.194	.202
On slope	.012	.003	.010
Haulage	.650	.658	.573
Switching and spragging	.020	.026	.003
Coupling	.008	.007	.025
Falling from trips	.030	.023	.035
Run over	.241	.250	.236
Caught between car and rib	.136	.141	.142
Caught between car and roof	.027	.026	.028
Runaway cars	.057	.030	.060
Miscellaneous	.131	.155	.044
Gas or Dust Explosions	.636	.777	.567
Open light	.191	.076	.091
Defective safety lamp	.005	.010	---
Electric arc	.081	.016	.025
Shot	.077	.158	.038
Powder explosion	.005	.010	.003
Miscellaneous	.277	.507	.410
Explosives	.145	.129	.202
Transportation	---	---	.003
Charging	.006	.013	.006
Suffocation	.008	.007	---
Drilling into old holes	.003	---	---
Striking in loose rocks	---	---	---
Thawing	---	---	---
Caps & detonators	.001	.003	.010
Unguarded shots	.006	.007	.006
Returned too soon	.013	.013	.010
Premature shot	.048	.030	.066
Sparks from lamp, etc	.005	.010	.010
Delayed shots	.015	.013	.019
Shot breaking through rib	.011	.007	.025
Miscellaneous	.029	.026	.047
Electricity	.143	.122	.151
Direct contact with trolley wire	.050	.033	.050
Tools striking trolley wire	.003	.007	.003
Contact with mining machine	.013	.003	.016
Contact with machine feed wire	.009	.013	.019
Contact with haulage motor	.003	---	---
Miscellaneous	.065	.066	.063

TABLE 2.- COAL-MINE FATALITIES DURING JUNE, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																													
Falls of roof.........	3	--	1	1	---	1	--	---	2	--	---	--	---	3	---	---	1	15	---	--	---	1	--	---	22	---	50	25	75
Falls of side.........	---	--	---	1	---	---	--	---	--	1	---	--	---	---	---	---	--	---	---	--	---	--	--	---	7	1	10	3	13
Haulage...............	---	--	---	---	---	---	--	---	2	--	---	--	1	---	---	---	1	2	---	--	---	--	--	---	8	---	14	3	17
Gas or dust explosions.	1	--	---	---	---	---	--	---	--	--	---	--	---	---	---	1	--	---	---	--	---	--	--	---	3	1	6	5	11
Explosives............	---	--	---	---	---	1	--	1	--	--	---	--	---	---	---	2	--	4	---	--	---	--	--	---	1	---	9	6	15
Suffocated by mine gases	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	2	2
Electricity...........	---	--	---	---	---	---	--	---	--	--	---	--	1	---	---	---	--	2	---	--	---	--	1	1	1	---	6	1	7
Animals...............	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	--	---
Mining machines.......	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	1	---	1	--	1
Mine fires............	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	--	---
Other causes..........	---	--	---	---	---	---	--	---	1	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	1	---	2	2	4
TOTAL...........	4	--	1	2	---	2	--	1	5	1	---	--	2	3	---	3	2	23	---	--	---	1	1	1	44	2	98	47	145
SHAFT																													
Persons falling.......	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	--	---
Objects falling.......	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	--	---
Cages, skips..........	---	--	---	1	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	1	--	1
Other causes..........	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	--	---
TOTAL...........	---	--	---	1	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	1	--	1
SURFACE																													
Mine cars.............	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	1	---	1	1	2
Electricity...........	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	2	---	--	---	--	--	---	1	---	3	1	4
Machinery.............	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	--	---
Boiler explosions......	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	--	---
Railway cars..........	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	---	---	--	---	--	--	---	--	---	---	--	---
Other causes..........	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	2	---	--	---	--	--	---	2	---	4	--	4
TOTAL...........	---	--	---	---	---	---	--	---	--	--	---	--	---	---	---	---	--	4	---	--	---	--	--	---	4	---	8	2	10
GRAND TOTAL, June, 1927	4	--	1	3	0	2	0	1	5	1	0	0	2	3	0	3	2	27	0	0	0	1	1	1	48	2	107	49	156
GRAND TOTAL, June, 1926	13	--	0	0	3	5	0	0	16	3	0	0	0	2	0	3	0	21	0	3	0	2	3	0	45	4	123	48	171

TABLE 3.- COAL-MINE FATALITIES DURING 1927, BY MONTHS AND STATES

MONTH	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January................	6	--	2	8	19	3	1	-	23	--	1	1	1	2	-	7	2	35	-	3	-	1	2	1	43	4	165	45	210
February................	7	--	2	5	11	6	1	2	10	--	-	-	1	1	2	9	2	30	-	-	-	5	5	2	35	-	136	41	177
March................	6	--	-	7	23	7	1	2	6	--	-	-	-	2	-	6	2	35	-	3	-	2	3	1	38	1	145	40	185
April................	6	--	-	2	4	-	2	-	2	--	1	-	1	-	-	3	2	33	-	1	-	3	3	7	144	-	214	40	254
May................	6	--	1	8	4	-	1	-	11	--	-	-	-	1	-	5	1	24	-	-	-	3	9	2	50	1	127	53	180
June................	4	--	1	3	-	2	-	1	5	1	-	-	2	3	-	3	2	27	-	-	-	1	1	1	48	2	107	49	156
TOTAL, 6 months.....	35	--	6	33	61	18	6	5	57	1	2	1	5	9	2	33	11	184	-	7	-	15	23	14	358	8	894	268	1162

TABLE 4.- AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED

Cause of accident	Per cent of total, 1917-1926	Death rates per million short tons						
		Average for 10 years 1917-1926	Year 1925	Year 1926	Average for June 10 years 1917-1926	1927		1926
						May	June	June
Bituminous Mines								
1. Falls of roof and coal	48.96	1.759	1.750	1.717	1.927	1.864	1.638	1.667
2. Underground haulage	18.18	.653	.586	.655	.650	.593	.382	.595
3. Explosions of gas or coal dust:								
Local explosions	2.91	.104	.112	.080	.136	.057	.164	.167
Major explosions	10.84	.390	.469	.565	.118	.424	- -	- -
4. Explosives	3.30	.118	.094	.080	.103	.057	.246	.095
5. Electricity	4.01	.144	.154	.161	.189	.282	.164	.238
6. Mining machines	1.33	.048	.067	.045	.033	.057	.027	.095
7. Other causes underground	2.93	.105	.089	.067	.111	.035	.055	.048
8. All causes underground	92.46	3.321	3.321	3.370	3.267	3.419	2.676	2.905
9. All shaft accidents	1.73	.062	.058	.047	.063	- -	.027	- -
10. All accidents on surface	5.81	.209	.148	.147	.224	.169	.218	.024
11. All accidents	100.00	3.592	3.527	3.564	3.554	3.588	2.921	2.929
Anthracite Mines								
1. Falls of roof and coal	42.71	2.496	2.750	2.588	2.651	2.874	3.858	2.462
2. Underground haulage	12.75	.745	.906	.612	.646	.500	.413	.672
3. Explosions of gas:								
Local explosions	6.71	.392	.421	.329	.632	.250	.689	.559
Major explosions	1.51	.088	.275	.247	.257	.875	- -	- -
4. Explosives	12.37	.723	.857	.588	1.830	1.374	.827	.559
5. Electricity	1.00	.059	.065	.024	.094	.125	.138	- -
6. Other causes underground	8.18	.478	.323	.459	.471	.625	.551	.559
7. All causes underground	85.23	4.981	5.597	4.847	6.581	6.623	6.476	4.811
8. All shaft accidents	2.30	.134	.065	.094	.094	- -	- -	- -
9. All accidents on surface	12.47	.729	.809	.388	.606	- -	.276	.559
10. All accidents	100.00	5.844	6.471	5.329	7.281	6.623	6.752	5.370

Serial No. 2822
July, 1927.

REPORTS OF INVESTIGATIONS

BUREAU OF MINES -- DEPARTMENT OF COMMERCE

THE USE OF SOLVENTS FOR DEWAXING PARAFFIN-BASE CRUDE OIL.

By H. M. Smith[1]

Introduction

In studying the chemistry of lubricating-oil fractions from so-called "paraffin-base" crudes, one of the first requisites is a method for the separation and removal of waxy material. A method utilizing solvents for this purpose is described in this report, together with preliminary experiments with solvents that led to its development. The solvents actually used are secondary butyl alcohol, acetone, and mixtures of these. Isopropyl alcohol was also studied.

Preliminary Experiments

In previous work on "intermediate-base" crude oil, following the work of Wyant and Marsh[2], acetone had been used for laboratory separations of oil and wax. When acetone was tried for the separation of the waxes and oils of "paraffin-base" crude, the volume of acetone required (80 parts to 1 part of oil) was found to be too great for large-scale work. For this reason the effectiveness of other solvents was studied; the separation by acetone, however, was used as a standard.

It is well known that ethyl alcohol dissolves hydrocarbon oils slightly, and that amyl alcohol is a very good solvent. It seemed probable therefore, that propyl or butyl alcohols could be used to advantage. The availability of isopropyl and secondary butyl alcohols, both made from the gases from petroleum cracking stills, led to a study of their solvent action.

Isopropyl alcohol, $CH_3 - CHOH - CH_3$, forms a constant boiling mixture (B.P. 80.4°C.) consisting of 91 per cent alcohol and 9 per cent water by volume. The commercial material tried in this work had approximately this composition.

Test-tube experiments indicated that the isopropyl alcohol as received did not offer any advantage over acetone, but after dehydrating with solid NaOH and anhydrous $CuSO_4$, it was an excellent solvent.

---

[1] - Assistant petroleum chemist, Petroleum Experiment Station, Bartlesville, Oklahoma, Bureau of Mines, Department of Commerce.

[2] - Wyant, L. D., and Marsh, L. G., Paraffin Wax, Tech. Paper 368, 1925, 26 pp.

The secondary butyl alcohol, $CH_3 - CHOH - CH_2 - CH_3$, had a boiling range of 94° to 102°C. and had been dehydrated to about 98 per cent by volume. This alcohol appeared to dissolve the oil readily and to give good separations of the oil and wax.

Accordingly, the following experiments were made with these two alcohols. The oil used was a paraffin-base crude, from which the gasoline had been distilled.

Sufficient solvent was added to 200 cc. of the oil to dissolve it at 50°C. The solution was then cooled to 0°C., and filtered by suction. The residuum on the filter was again dissolved, cooled and filtered. The solvents were then removed by distillation from the oil and wax, and the respective recoveries determined.

The isopropyl alcohol offered no especial difficulties in this method, but the viscosity of the secondary butyl alcohol caused the filtration to be rather slow, and as an ice bath was not used around the funnel, the temperature rose somewhat and some of the wax went back into solution, causing high results for the oil and correspondingly low values for the wax. An additional difficulty was the tendency of the crystals to go through the filter due to their small size. The results of these experiments are as follows:

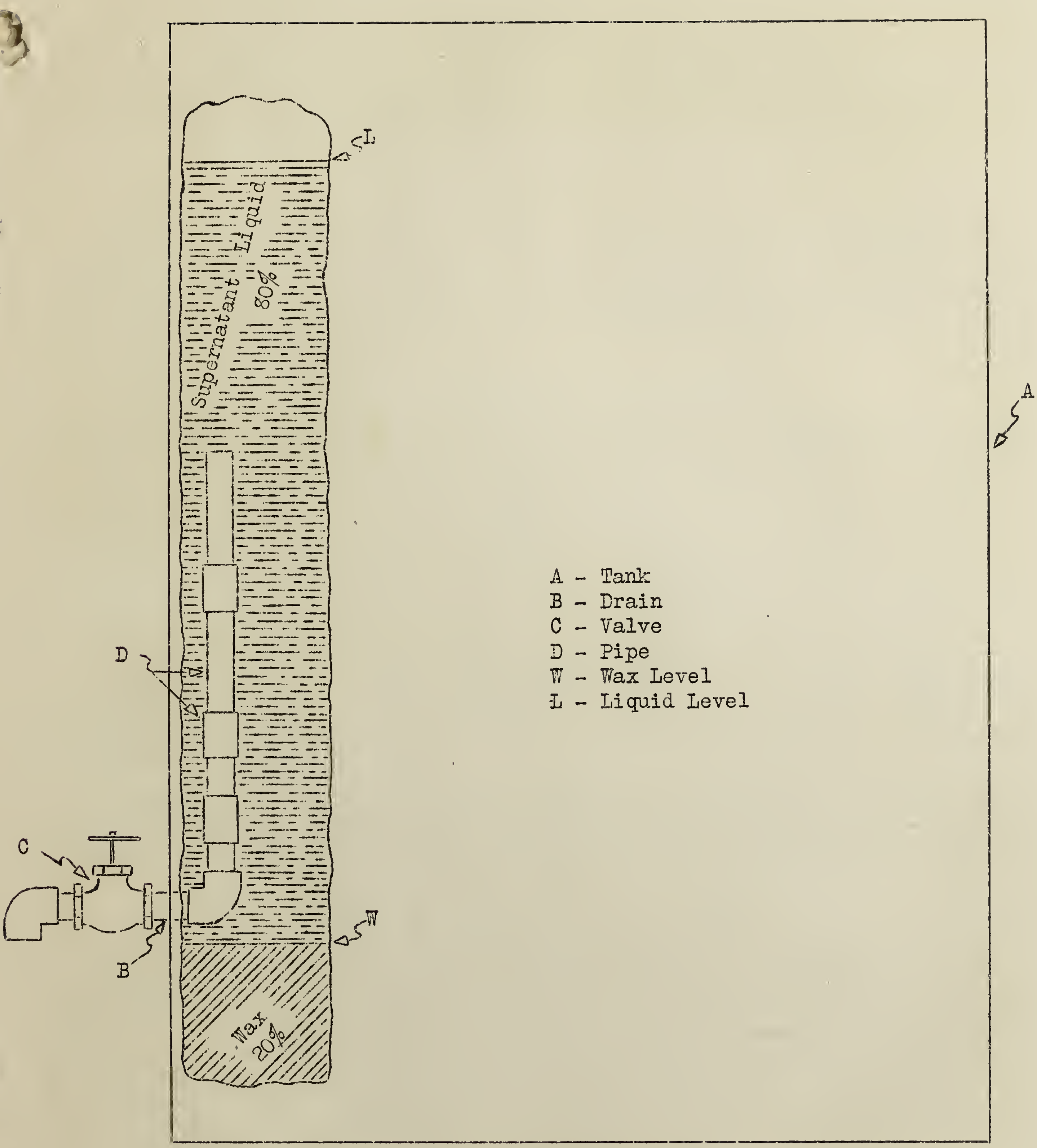
Table 1. - Results of Experiments, First Series.

Solvent	Oil per cent	Wax per cent	Loss per cent
Acetone	74.1	18.1	7.8
Isopropyl alcohol (dehydrated)	68.1	21.4	11.5
Secondary butyl alcohol	82.4	8.3	9.3

The loss in these analyses is due to evaporation of a part of the light fractions of the oil when the solvent is distilled.

Centrifuging

Since the dehydration of the isopropyl alcohol is rather inconvenient, further experiments were made with the secondary butyl alcohol. Two possibilities that suggested themselves were centrifuging and filtration in a filter press. Accordingly, portions of the oil and alcohol were fixed in the ratio of 1:1, 1:2 and 1:3. On hundred c.c. of each mixture were placed in graduated centrifuge tubes, warmed to complete solution and then chilled to 0°C. As soon as the prepared samples were thoroughly chilled they were centrifuged for five minutes to 3000 r.p.m. This threw the wax down in a very compact mass from all but the 1:1 mixture, which did not separate cleanly. The oil-solvent solution could be readily decanted from the solid wax in the 1:2 and 1:3 mixtures. The percentage of wax in both these mixtures as indicated by the amount in the bottom of the tube corresponded very closely with the figures obtained by the acetone method.



COLD SETTLING TANK

Figure 1.

Filtration

Filtration in a small experimental Shriver filter press using paper with cloth backing was not successful, as the pressures developed by the pump forced the small crystals through the filtering medium.

Cold Settling

Centrifuging was very successful, but because of limited equipment was very slow for the handling of large amounts; to overcome this difficulty cold settling was tried. Various mixtures of oil and solvents were prepared, placed in Florence flasks and allowed to stand at a temperature of 1 to 2°C. for 36 hours. The mixtures used, and the observations made at the end of 36 hours are given in the following table.

Table 2.- Results of Experiments With Cold Settling.

Test No.	Oil, c.c.	Solvent mixture		Precipitate		Supernatant Liquid	
		Sec. butyl alcohol, c.c.	Acetone c.c.	Size of particles	Condition, dry or oily	Per cent	Condition
1	500	500	-----	Very small	Dry	20	Cloudy
2	300	600	----	Small	Dry	65	Clear
3	500	250	250	Medium	Slightly oily	40	do
4	300	300	300	do	Slightly oily	75	Very clear
5	250	750	-----	Very small	Dry	65	Clear
6	300	400	200	Medium	Dry	60	Very clear
7	300	200	400	None	Mush	65	Clear
8	300	300	300[a]	None	Mush	65	Cloudy

[a] Undehydrated isopropyl alcohol.

Mixtures 4 and 6 gave the most promise considering the percentage and condition of the supernatant liquid; and accordingly the solutions indicated in Table 3 were made up and allowed to settle at 1 to 2°C. (34 to 36°F).

Practical Separation of Oil and Wax

With regard to time and efficiency, mixture No. 10, Table 3, was the best, and it was used in the actual separation of wax from 50 gallons of the topped paraffin-base oil. The apparatus used in the process is shown in figure 1. The drain, B, of $\frac{1}{2}$-inch pipe, is inserted through the side of the 50-gallon tank, A, in such a position that 75 per cent of the contents can be drawn off. It is closed on the outside by a valve, C, and on the inside is built up with short pipe nipples and couplings, D, to a height well above the level taken by the settled wax. These nipples and couplings are screwed on loosely by hand, and can be removed as the liquid is drawn off.

Table 3 - Results of Further Experiments with Cold Settling.

Test No.	Oil, c.c.	First addition of solvent[a]			Second addition of solvent			Recovery			
		Secondary-butyl alcohol, c.c.	Acetone, c.c.	Settled in 24 hours, %	Secondary-butyl alcohol, c.c.	Acetone c.c.	Settled in 24 hours, %	Oil %	Wax %	Loss %	Efficiency of recovery[b] %
9	800	800	400	60	800	400	75	70.2	22.4	7.4	95
10	600	800	400	75	800	400	75	70.2	21.8	8.0	95
11	300	300	300	75	300	300	75	61.5	29.8	8.7	85

[a] The supernatant liquid was drawn off of each mixture at the end of 24 hours, and the second addition of solvent used to work the wax crystals.

[b] Based on 74% of oil obtained by acetone method (See Table I).

Fifteen gallons of oil, 20 gallons of secondary butyl alcohol, and 10 gallons of acetone were thoroughly mixed in the tank, and then allowed to settle at 1 to 2°C (34-36°F). At the end of 24 hours, 30 gallons 66-2/3 per cent of clear supernatant liquid were drawn off, the wax level being approximately as shown by line W in figure 1. Twenty-five gallons of solvent were then added to the wax, the mixture stirred and again allowed to settle. At the end of 24 hours the entire supernatant liquid was drawn off.

Solvent Recovery

The solvent is removed from both the oil and wax by distillation with natural gas. A 5-liter flask in a bath of boiling water is a convenient still. A stream of natural gas is passed through the solution in the flask, and removes the solvent very rapidly. The recovered solvent may be used successfully for the wash mixture, especially when corrected for distillation loss by the addition of a small amount of acetone.

Altogether 140 kg. of gasoline-free oil were treated in this manner, and the recoveries were as follows: Oil, 72.8 per cent; wax, 25.7 per cent; loss, 1.5 per cent. The wax separated in this manner from this particular crude oil is very similar to yellow vaseline. The pour-point test of the dewaxed oil is 15°F., as against 25°F. for the gasoline free crude.

The above experiments indicate that secondary butyl alcohol has possibilities as a solvent for the removal of wax from paraffin-base crudes. Its solvent properties may be utilized to their fullest extent, or they may be modified by the admixture of another solvent such as acetone. The manner in which it is used depends upon the method of dewaxing.

Acknowledgments

This paper represents work done under a cooperative agreement between the U. S. Bureau of Mines, and the State of Oklahoma.

Acknowledgment is made to Mr. Henry N. Lyons of Henry L. Doherty Company, who suggested the use of these alcohols for this work, and to the Empire Refineries, Inc. who furnished the alcohol.- Reports of Investigations, Bureau of Mines, Department of Commerce.

STATE GEOLOGICAL SURVEY

Serial No. 2823.
July, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

CONSUMPTION OF EXPLOSIVES IN JUNE, 1927.

By W. W. Adams[1]

Explosives manufactured in the United States and sold in June 1927 for domestic consumption amounted to 326,800 kegs (8,170,000 pounds) of black blasting powder, 4,895,000 pounds of permissible explosives, and 27,787,000 pounds of high explosives other than permissibles, according to information furnished by manufacturing companies to the United States Bureau of Mines, Department of Commerce. These figures include an estimate of sales by several companies that did not furnish reports to the Bureau. Reports actually received showed sales of 320,289 kegs of black powder, 4,887,751 pounds of permissibles, and 26,108,290 pounds of other high explosives. All three classes of explosives showed reductions in quantities sold in June 1927 as compared with June 1926.

PERMISSIBLE EXPLOSIVES: Sales of permissible explosives in June brought the total sales during the first half of 1927 to 32,190,000 pounds, including 32,142,708 pounds actually reported and an estimate to cover sales by several non-reporting companies. The quantity sold thus far during the current year is about ten per cent more than the amount sold during the first six months a year ago. Nearly 96 per cent (95.9) of the explosives were for use in coal mines, 66.9 per cent being for bituminous mines and 29 per cent for anthracite mines. The quantity used at bituminous mines during the six months January to June has averaged 78 pounds of permissibles, or 30 per cent of the 261 pounds of all kinds of explosives per thousand tons of bituminous coal produced. The corresponding record for anthracite mines shows 747 pounds of all kinds of explosives per thousand tons of coal production, of which 228 pounds, or 30 per cent, were permissibles. Figures for bituminous coal mines for the past six months show an increasing proportion of permissible explosives used as compared with other classes of explosives. This increasing use of permissibles is encouraging from the standpoint of accident prevention in coal mines, particularly as regards accidents involving explosions of coal dust, as permissibles are less likely to ignite coal dust than are many other types of explosives. States using the largest quantities of permissible explosives during the first half of 1927, in each case more than 500,000 pounds, are Pennsylvania, West Virginia, Alabama, Kentucky, Illinois, and Virginia. The States of Kentucky and West Virginia showed a notable increase in the amount of permissible explosives used in 1927 as compared with the first six months of 1926.

BLACK BLASTING POWDER: The amount of black blasting powder sold for use in the United States during the six months, January to June 1927, was 2,543,100 kegs, or 63,577,500 pounds, including 2,492,241 kegs sold by reporting companies and an estimate to cover sales by several manufacturers that do not report their sales monthly. The figure for 1927 represents a reduction of eleven per cent as compared with the corresponding six-months' record last year. Eighty-five per cent of the total quantity was sold for use in coal mines, 73½ per cent being for bituminous mines and 11½ per cent for anthracite mines. The quarrying industry used about 5 per cent and an equal quantity was used in railway and other construction work. In the coal mining industry, the consumption of black blasting powder since January first has averaged 169 pounds, or 65 per cent, of a total of 261 pounds of all kinds of explosives per thousand tons of bituminous coal produced, while in the anthracite mines the average consumption of black powder was 177 pounds, or 24 per cent, of the 747 pounds of all classes of explosives used for each thousand tons of coal produced. States using the largest quantities of black powder during the past six months are Pennsylvania, Kentucky, Illinois, and West Virginia. Each of these States used more than 250,000 kegs of 25 pounds each. Kentucky, Oklahoma, and Texas used larger quantities of black powder than during the first half of 1926 while smaller quantities were reported for such coal-producing States as Alabama, Illinois, Indiana, Iowa, Kansas, Ohio, Pennsylvania, Virginia, and West Virginia.

---

[1] Statistician, Bureau of Mines, Department of Commerce.

OTHER HIGH EXPLOSIVES: Sales of high explosives, other than permissible explosives, during the first half of 1927 amounted to 152,116,000 pounds, including 142,928,559 pounds actually reported and an estimate of sales by several non-reporting companies. As compared with the first half of 1926, the volume of sales in 1927 represents an increase of a little more than one per cent. Metal mining was the largest consumer of this class of explosives during the past six months, the consumption amounting to 31.7 per cent of the total quantity used for all purposes. Quarrying and nonmetallic mineral mining used 27.9 per cent; coal mining 11.8 per cent, and railway and other construction work 15.3 per cent. The remaining 13.3 per cent was used for miscellaneous purposes. Of the 11.8 per cent of this class of explosives used at coal mines, 9.2 per cent was used at anthracite mines and 2.6 per cent at bituminous mines. The amount used at anthracite mines since January first has averaged 342 pounds per thousand tons of coal produced, or 46 per cent of the 747 pounds of all kinds of explosives per thousand tons. The corresponding six-months' consumption at bituminous coal mines was 14 pounds of high explosives, or 5 per cent of the 261 pounds of all kinds of explosives used per thousand tons of coal produced. Records for the past six months show that the largest consumption of this class of explosives was in the States of Pennsylvania, Michigan, California, New York, Minnesota, Oklahoma, Florida, and Ohio. About half of Pennsylvania's consumption was for anthracite mines, and about one-third was for quarries or nonmetallic mineral mines. In California, about one-third of the explosives were used in metal mines and quarries and more than one-third in construction work. Nearly four-fifths of Michigan's allotment was for metal mines and about one-fifth for stone quarries. In New York the quarrying and nonmetallic mineral industries were the principal consumers, nearly three-fifths of the explosives being used in this manner, and about one-fourth in construction work. In Minnesota the metal-mining industry used about 90 per cent of the State's total consumption of high explosives; in Oklahoma, about 80 per cent. In Florida nearly 40 per cent was for nonmetallic mineral mines and quarries and about 40 per cent for construction work. In Ohio the principal consumer was the quarrying and nonmetallic mining industry, this class of work accounting for nearly 80 per cent of the State's consumption of high explosives during the first half of 1927.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in June were more than 264,600 kegs, showed that the mills were operated to 40 per cent of their capacity in June as compared with 29 per cent in May, 31 per cent in April, and 32 per cent in June last year. The amount of explosives remaining on hand at the close of June represented 52 per cent of one month's manufacturing capacity of the mills reporting, as compared with 44 per cent at the close of June a year ago.

	June, 1926	June, 1927	Jan.-June, 1927
Capacity (Kegs)..........	953,583	796,083	4,776,498
Manufactured.............	304,443	318,504	1,943,198
Per cent of capacity.....	32	40	41
Shipments................	323,300	295,636	1,936,604
Per cent of capacity.....	34	37	41
Sales....................	305,422	264,625	1,890,160
Per cent of capacity.....	32	33	40
Stocks, end of month.....	421,365	413,095	413,095
Per cent of capacity.....	44	52	9

The following percentage figures show the extent of capacity to which mills manufacturing black powder were operated in 1924, 1925, 1926, and in the months of January to June 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month.

	Manufactured	Shipments	Sales	Stocks
Year 1924...........	41	41	41	3.8
Year 1925...........	38	39	38	3.2
Year 1926...........	40	40	39	3.6
Average, 6 mos. 1926	37	37	36	7.3
1927				
January.............	54	55	56	50
February............	54	47	45	58
March...............	36	36	38	58
April...............	31	32	30	57
May.................	29	36	35	49
June................	40	37	33	52
Average, 6 months...	41	41	40	8.6

Reports from 23 mills that sold more than 25 million pounds of permissibles and other high explosives in June showed that the mills were operated to 65 per cent of their capacity in June as compared with 73 per cent in May, 66 per cent in April, and 76 per cent in June last year. The amount of explosives remaining on hand at the close of June represented 17 per cent of one month's manufacturing capacity of the mills reporting, as compared with 15 per cent at the close of June a year ago.

	June, 1926	June, 1927	Jan.-June, 1927
Capacity (Pounds).........	39,153,332	40,195,000	234,920,000
Manufactured.............	29,881,136	26,157,861	153,090,364
Per cent of capacity......	76	65	65
Shipments................	29,792,118	26,392,347	153,048,523
Per cent of capacity......	76	66	65
Sales....................	27,932,656	25,738,471	146,710,902
Per cent of capacity......	71	64	62
Stocks, end of month......	5,923,543	6,661,833	6,661,833
Per cent of capacity......	15	17	2.8

The percentage of full-time capacity to which mills manufacturing permissibles and other explosives were operated in 1924, 1925, 1926, and in the months of January to June 1927, is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining on hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924..............	62	62	59	1.4
Year 1925..............	62	62	59	1.5
Year 1926..............	68	68	64	1.4
Average, 6 mos. 1926...	65	65	61	2.5
1927				
January................	59	58	57	19
February...............	63	62	57	20
March..................	64	64	62	20
April..................	66	69	65	17
May....................	73	72	69	18
June...................	65	66	64	17
Average, 6 months......	65	65	62	2.8

PYROTOL: During the first six months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 8,920,960 pounds of pyrotol of which 1,091,750 pounds represented shipments in June. During the corresponding six months last year the shipments amounted to 9,629,000 pounds. Most of the pyrotol shipped was for use by farmers in clearing land. Table D shows the amount of pyrotol shipped to each State in June 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal-mining operations in each State from January to June, 1927 is shown in Table C. Table D shows the quantity of pyrotol distributed in June to the various States.--Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE A - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during June, 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	8,415	661,475	379,350
Alaska	56	176,200	-
Arizona	3,290	136,600	-
Arkansas	4,739	73,650	20,350
California	5,565	2,033,725	-
Colorado	2,449	519,715	62,700
Connecticut	77	134,850	-
Delaware	30	13,700	-
Florida	1,800	955,100	-
Georgia	338	88,625	-
Idaho	432	449,800	-
Illinois	5,362	559,637	22,050
Indiana	20,797	336,175	48,125
Iowa	2,065	206,150	500
Kansas	6,292	475,470	3,800
Kentucky	49,671	404,200	208,225
Louisiana	-	161,185	-
Maine	113	47,375	-
Maryland	3,762	259,275	12,500
Massachusetts	124	101,300	-
Michigan	412	1,866,725	-
Minnesota	8,377	1,435,151	-
Mississippi	1	79,050	-
Missouri	3,542	933,750	335
Montana	4,032	489,357	2,850
Nebraska	65	17,150	-
Nevada	3,880	381,450	-
New Hampshire	30	31,150	-
New Jersey	35	367,250	-
New Mexico	2,726	34,150	24,000
New York	831	1,476,225	12,200
N. Carolina	2,834	324,850	1,750
N. Dakota	1,702	5,925	200
Ohio	10,964	1,035,925	17,350
Oklahoma	8,643	696,450	13,001
Oregon	2,689	413,100	-
Pennsylvania	81,709	4,463,187	2,495,815
Rhode Island	23	7,500	-
S. Carolina	201	92,350	-
S. Dakota	118	96,080	-
Tennessee	9,517	291,825	11,250
Texas	5,893	949,495	12,450
Utah	2,640	738,345	27,500
Vermont	33	13,800	-
Virginia	2,047	299,825	155,500
Washington	5,229	673,143	73,750
West Virginia	43,926	527,900	1,258,600
Wisconsin	884	432,275	-
Wyoming	1,929	140,700	23,600
TOTAL JUNE 1927	320,289	26,108,290	4,887,751

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first six months of 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	55,451	4,355,569	2,531,000
Alaska	256	1,106,990	56,700
Arizona	11,195	819,925	-
Arkansas	25,558	691,156	72,650
California	35,059	8,854,110	-
Colorado	24,822	2,692,426	378,500
Connecticut	136	785,200	-
Delaware	30	41,470	-
Florida	11,914	5,417,722	-
Georgia	7,507	1,005,225	-
Idaho	2,522	2,171,809	8,850
Illinois	313,276	3,661,015	977,700
Indiana	227,776	1,656,500	270,950
Iowa	56,550	1,207,775	2,950
Kansas	94,439	3,808,751	157,765
Kentucky	330,274	2,205,825	1,702,825
Louisiana	350	1,207,371	48,750
Maine	939	320,425	-
Maryland and D. C.	14,187	1,245,825	84,250
Massachusetts	907	581,775	-
Michigan	3,616	10,474,775	-
Minnesota	17,074	6,128,509	-
Mississippi	1,033	623,950	-
Missouri	35,998	4,866,039	75,581
Montana	25,483	3,252,522	13,850
Nebraska	1,335	89,875	-
Nevada	19,256	1,769,425	200
New Hampshire	220	80,175	-
New Jersey	56	1,548,625	-
New Mexico	8,968	293,975	168,050
New York	6,366	7,298,449	28,100
N. Carolina	16,432	2,011,825	4,750
N. Dakota	9,223	58,157	5,975
Ohio	126,023	5,367,095	104,600
Oklahoma	55,084	5,577,442	111,142
Oregon	11,662	2,073,425	-
Pennsylvania	495,173	23,704,269	16,059,545
Rhode Island	90	192,850	-
S. Carolina	1,651	446,750	-
S. Dakota	349	677,485	1,300
Tennessee	55,613	1,956,025	167,700
Texas	47,037	4,337,823	14,850
Utah	9,050	4,255,870	380,150
Vermont	2,102	236,950	-
Virginia	30,862	1,929,550	736,900
Washington	21,603	4,009,235	333,575
West Virginia	262,135	2,622,325	7,234,000
Wisconsin	3,140	2,665,825	50
Wyoming	12,429	665,475	409,500
TOTAL 1st 6 MOS. 1927	2,492,241	142,928,559	32,142,708

JUNE, 1927

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs	Pounds	Pounds
Quantity used for:			
Coal mining....................	243,423	3,044,275	4,704,500
Metal mining...................	12,670	7,693,169	17,000
Quarrying and nonmetallic mineral mining..............	22,716	7,982,875	34,025
Railway and other construction work......................	26,224	4,106,473	1,925 Rtd.
All other purposes...........	15,256	3,281,498	134,151
TOTAL JUNE 1927.................	320,289	26,108,290	4,887,751

JANUARY TO JUNE, 1927, INCLUSIVE.

Quantity used for:			
Coal mining....................	2,115,037	16,853,276	30,837,705
Metal mining...................	41,746	45,253,984	45,975
Quarrying and nonmetallic mineral mining..............	123,124	39,947,966	247,520
Railway and other construction work......................	125,006	21,808,845	87,095
All other purposes...........	87,328	19,064,488	924,413
TOTAL 1st 6 MOS. 1927...........	2,492,241	142,928,559	32,142,708

TABLE C - Quantity of explosives sold for use in COAL MINES in June 1927 by manufacturers rendering monthly reports.
(Including cumulative figures for the first six months of 1927)

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama.........	6,307	42,572	47,450	303,594	376,400	2,511,200
Arkansas........	4,639	25,138	12,300	34,450	1,000	7,300
Colorado........	1,657	17,127	25,000	98,225	52,900	344,850
Illinois........	4,861	309,620	7,200	176,050	20,050	895,075
Indiana.........	20,487	223,723	71,800	257,450	42,425	246,950
Iowa............	2,037	53,801	4,200	61,100	500	1,500
Kansas..........	4,978	90,266	47,275	323,526	3,500	156,515
Kentucky........	47,228	313,509	57,150	446,900	178,375	1,537,655
Maryland........	3,300	11,316	1,500	20,000	3,700	46,600
Michigan........	- -	2,117	4,100	25,000	- -	- -
Missouri........	1,164	26,028	13,850	74,900	285	27,131
Montana.........	4,019	18,903	2,100	6,250	2,850	6,850
New Mexico......	900	2,805	- -	5,350	24,000	167,550
North Dakota....	1,673	8,944	675	33,525	200	5,975
Ohio............	8,540	108,831	35,375	243,050	16,050	42,750
Oklahoma........	6,945	48,679	7,050	66,450	6,700	91,079
Penna.(Bitum)...	20,916	177,865	122,775	725,675	820,740	6,493,925
Tennessee.......	5,753	45,937	7,050	83,650	10,700	160,300
Texas...........	910	12,303	2,300	5,700	- -	- -
Utah............	- -	- -	- -	27,550	27,500	373,650
Virginia........	1,451	25,105	10,100	124,100	155,100	724,950
Washington......	865	7,389	13,200	40,400	56,750	232,150
West Virginia...	41,127	248,264	86,250	471,550	1,248,900	7,013,625
Wyoming.........	4	7,371	2,500	25,300	23,100	349,000
Other States....	850	4,185	500	27,425	1,750	69,600
Total (Bitum)...	190,611	1,831,798	581,700	3,707,170	3,073,475	21,506,180
Penna. (Anth)...	52,812	283,239	2,462,575	13,146,106	1,631,025	9,331,525
Grand Total as reported.....	243,423	2,115,037	3,044,275	16,853,276	4,704,500	30,837,705
Est. total inc.) non-reporting) companies)	Anth.	288,900		13,995,000		9,345,000
	Bitum.	1,869,100		3,940,000		21,539,000
Total reported plus estimate...		2,158,000		17,935,000		30,884,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period June 1, 1927 to June 30, 1927.

State	State Highway Departments Roads	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
Arkansas..........	- -	- -	- -	30,000	30,000
California........	- -	- -	- -	42,000	42,000
Idaho.............	- -	16,000	24,000	600	40,600
Iowa..............	- -	43,000	- -	- -	43,000
Kansas............	28,000	- -	- -	- -	28,000
Michigan..........	16,000	20,000	- -	300	36,300
Minnesota.........	26,000	225,000	- -	- -	251,000
Montana...........	- -	22,000	- -	- -	22,000
Nebraska..........	20,000	25,000	- -	- -	45,000
Oregon............	12,000	41,800	84,300	- -	138,100
Tennessee.........	20,000	- -	- -	- -	20,000
Virginia..........	- -	20,000	- -	- -	20,000
Washington........	103,300	119,450	- -	- -	222,750
Wisconsin.........	- -	153,000	- -	- -	153,000
Total June........	225,300	685,250	108,300	72,900	1,091,750
Total May.........	162,000	825,500	26,000	352,100	1,365,600
Total April.......	281,550	1,669,550	7,500	222,000	2,180,600
Total March.......	249,500	1,916,860	- -	108,700	2,275,060
Total February....	170,750	1,020,150	- -	- -	1,190,900
Total January.....	93,000	704,050	- -	20,000	817,050
Grand Total.......	1,182,100	6,821,360	141,800	775,700	8,920,960

622.09
Un32mo
cop.2

Serial No. 2824.
August, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

ANALYSES OF CRUDE OILS FROM THE SEMINOLE DISTRICT, OKLAHOMA

By A. J. Kraemer[1]

THE LIBRARY OF THE
JUL 2 3 1950
UNIVERSITY OF ILLINOIS

Introduction

The Bureau of Mines for a number of years has been carrying on an investigation of properties of crude petroleum from producing fields in the United States and the Western Hemisphere, and has published a series of reports on these fields, including oil fields of Oklahoma[2].

Acknowledgments

Thanks are due to R. R. Brandenthaler and Peter Grandone, of the Petroleum Experiment Station of the Bureau of Mines, at Bartlesville, Oklahoma, who reviewed the manuscript and contributed valuable suggestions. The samples were analyzed under the direction of E. C. Lane at the Bartlesville station of the Bureau of Mines.

Production Data.

The Seminole District is situated in the center of Seminole County, in east Central Oklahoma, and extends over a region which has for a long time been regarded as favorable by petroleum geologists. The discovery well was the Indian Territory Illuminating Oil Company's well No. 1 Dyer, section 24-9-6, in the Hunton lime at a depth of 3900 feet. This well was the incentive for the intensive drilling campaign which made the district one of the most productive in the history of the petroleum industry in the United States. In July, 1926, the Independent Oil and Gas Company and R. F. Garland drilled a well southwest of the Indian Territory Illuminating Oil Company well, and found production in the Wilcox sand in Section 26-9-6, at 4000-4100 feet. This well attained a peak production of 8000 barrels. Within 60 days from the bringing in of the Independent-Garland well, more than 100 wells were being drilled in the adjacent territory. The production of the Seminole District increased steadily and reached a peak of 525,610 barrels on July 30, 1927 which is the highest daily production for the district to date. This is the largest production of light oil from any single area in the history of the petroleum industry in the United States.

---

[1] Associate petroleum chemist, Washington, D. C., Bureau of Mines, Department of Commerce.

[2] Dean, E. W., Bauer, A. D., Cooke, M. B., and Bopp, C. R., Properties of typical crude oils from the producing fields of Oklahoma; Reports of Investigations, Bureau of Mines, Serial 2364, June, 1922.

In December, 1926, the completion of unusually large wells caused a congestion of the available pipe line facilities, which initiated price cuts, storage programs, and attempts to reach an agreement to curtail production. Although these factors did not actually decrease the rate of production of the field, they undoubtedly contributed to restrain the yield below what it would have been if crude oil prices had remained where they stood in December, 1926.

The Seminole District at present consists of four pools: (1) Seminole Pool, which is in township 9-6; (2) Bowlegs, which is in township 8-6; (3) Earlsboro, in township 9-5, and (4) Searight, which is in township 10-6. The following table showing the production of the Seminole District for the 24 hours ending 7 a.m. June 25, 1927, is taken from data in the "Oil and Gas Journal," June 30, 1927.

	Wells	Production	
Seminole................	306	104,100	bbls.
Bowlegs.................	122	172,928	"
Earlsboro...............	79	92,311	"
Searight................	43	36,093	"
Total...........	550	405,432	"

Discussion of Results

For a discussion of the methods used by the Bureau of Mines in analyzing crude oil see Bulletin 207.[3] For a discussion of the interpretation of crude oil analyses, see Serial No. 2806.[4] Table I summarizes the results of these analyses by presenting some of the figures indicating physical and chemical properties of the crudes. Table 2 presents figures for the gravities of the fractions distilling at atmospheric pressure between 250° and 275° C, and also the cloud points of the fractions distilling between 275° and 300° C. at 40 mm. absolute pressure. These figures indicate the "base" of a crude oil.[4]

Gravities are reported in A.P.I. degrees. This is the scale formerly known in the American Petroleum industry as "Baume," based on the modulus 141.5 as distinguished from the Baume scale based on the modulus 140.0.[5]

Although there are a number of producing sands in the Seminole District, it does not seem possible to ascribe definite and distinctive characteristics to the production from any of the sands. The Wilcox is the most productive sand in all of the pools in the district. On the basis of the samples that the Bureau of Mines has analyzed, (not all of which are included in the report) the gravity of crude oil from the Wilcox sand in this district ranges from 37.6° to 43.2° A.P.I., with the average about 40° A.P.I. The sulphur content ranges from 0.26% to 0.43% with the average about 0.33%. The "gasoline and naphtha" content ranges from 34.1% to 41.3%, with the average about 38.4%. The production from the Hunton lime ranges in gravity between 37.8° and 40.4° A.P.I., with the average about 38.8° A.P.I. The sulphur content ranges from 0.22% to 0.30%, with the average about 0.26%. The "gasoline and naphtha" content of the crude from the Hunton lime ranges from 34.7% to 37.3%, with the average about 36.0%.

---

[3] Bureau of Mines Bulletin 207, "The Analytical Distillation of Petroleum and its Products" by E.W. Dean and others. Obtainable from the Government Printing Office, Washington, D. C. at 15 cents a copy.

[4] Smith, N.A.C. The Interpretation of Crude Oil Analyses, Reprts of Investigations, Bureau of Mines, Serial No. 2806, May, 1927.

[5] A concise statement of the reasons for the general adoption of the A.P.I. gravity scale has been prepared by the American Petroleum Institute, 250 Park Ave., New York, N. Y.

TABLE I

Data showing sources of samples and some of the figures indicating physical and chemical properties

Sample No.	Field	Sand	Depth Feet	Properties of Crude				Gasoline Fraction		Viscosity at 100°F. of Vacuum Fractions			% Carbon Residue of Residuum
				°A.P.I.	%S	Viscosity at 100°F	Pour test	%	°A.P.I.	225-250	250-275	275-300	
27335	Seminole	Wilcox	4136-4138	39.6	0.33	39	(a)	38.6	61.0	61	91	165	7.3
27339	do	do	4128-4129	39.8	.38	38	(a)	40.1	61.0	60	89	165	7.7
27240	Bowlegs	do	4194-4200	38.2	.31	43	(a)	37.1	60.8	58	87	165	6.8
27343	do	do	4111-4134	40.9	.30	38	(a)	39.1	62.9	60	93	175	6.8
27337	Earlsboro	do	4230-4234	43.2	.31	37	(a)	41.3	63.4	61	95	185	6.1
27236	do	do	4257-4283	39.6	.30	46	(a)	34.1	62.6	58	89	165	5.5
27377	Searight	do	4502-4508	37.6	.35	45	(a)	34.7	60.0	62	99	180	6.5
27336	Seminole	Hunton	--	37.8	.28	42	(a)	35.3	59.2	60	95	180	6.9
27381	Searight	do	4055-4155	38.2	.24	41	(a)	36.0	59.5	61	93	185	6.0
27378	do	Earlsboro	3534-3570	38.4	.20	44	(a)	35.8	60.5	63	100	195	5.3
27379	Earlsboro	do	3417-3460	40.2	.25	42	(a)	37.9	62.6	61	95	185	5.4
27243	Seminole	Cromwell	3503-3517	37.8	.14	47	(a)	32.3	59.5	61	91	165	5.1
27566	do	Viola	4171-4256	36.2	.47	45	(a)	34.7	56.7	60	91	168	10.5

(a) Below 5° F.

TABLE 2

Data indicating the "base" of the crude oil.

Sample No.	Field	Sand	Depth	Fraction distilling at atmospheric pressure between 250-275°C. (527-572°F.)		Fraction distilling at 40 mm. vacuum between 275-300°C. (527-572°F.)	Base of Crude
				Sp. Gr.	°A.P.I.	Cloud point °F.	
27335	Seminole	Wilcox	4136-4138	.840	37.0	80	Intermediate
27339	do	do	4128-4129	.841	36.8	85	do
27240	Bowlegs	do	4194-4200	.838	37.4	80	do
27343	do	do	4111-4134	.837	37.6	80	do
27236	Earlsboro	do	4257-4283	.834	38.2	75	do
27337	do	do	4230-4234	.841	36.8	80	do
27377	Searight	do	4502-4508	.835	38.0	80	do
27336	Seminole	Hunton	--	.837	37.6	80	do
27381	Searight	do	4055-4155	.836	37.8	75	do
27378	do	Earlsboro	3534-3570	.834	38.2	80	do
27379	Earlsboro	do	3417-3460	.833	38.4	80	do
27243	Seminole	Cromwell	3503-3517	.832	38.6	80	do
27566	do	Viola	4171-4256	.839	37.2	92	do

Sample Number 27335

Oklahoma	Seminole Field		Seminole County
Indian Territory Illuminating Oil Co.			Well No. 4
Section 23-9N-6E Indian		Wilcox Sand	4136-4138 ft.
Specific gravity, 0.827			A.P.I. gravity, 39.6°
Per cent sulphur, 0.33			Per cent water, nil
Saybolt Universal viscosity at 70°F., 42 sed.			Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 39 sec.			Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation   Barometer 737 mm. First Drop: 29°C. (84 F.)

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	3.3	3.3	0.643	88.6			Up to 122
50 - 75	3.4	6.7	.669	80.0			122 - 167
75 - 100	6.5	13.2	.709	68.1			167 - 212
100 - 125	7.7	20.9	.736	60.8			212 - 257
125 - 150	6.6	27.5	.757	55.4			257 - 302
150 - 175	5.8	33.3	.777	50.6			302 - 347
175 - 200	5.3	38.6	.794	46.7			347 - 392
200 - 225	4.9	43.5	.810	43.2			392 - 437
225 - 250	5.2	48.7	.826	39.8			437 - 482
250 - 275	5.8	54.5	.840	37.0			482 - 527

Vacuum distillation at 40 mm.

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	3.1	3.1	.859	33.2	41	10	Up to 392
200 - 225	5.3	8.4	.865	32.1	49	25	392 - 437
225 - 250	4.6	13.0	.879	29.5	61	45	437 - 482
250 - 275	4.1	17.1	.893	27.0	91	65	482 - 527
275 - 300	4.9	22.0	.905	24.9	165	80	527 - 572

Carbon residue of residuum 7.3%. Carbon residue of crude 1.6%.

APPROXIMATE SUMMARY

	Per cent	Sp.gr.	°A.P.I.	Viscosity
Light gasoline	13.2	0.683	76.0	
Total gasoline and naphtha	38.6	.735	61.0	
Kerosene distillate	4.9	.810	43.2	
Gas oil	17.3	.844	36.2	
Nonviscous lubricating distillate	9.8	.866-0.895	31.9-26.6	50-100
Medium lubricating distillate	5.9	.895- .909	26.6-24.2	100-200
Viscous lubricating distillate	--	- -	- -	Above 200
Residuum	22.1	0.958	16.2	
Distillation loss	1.4	- -	- -	

Sample Number 27339

Oklahoma	Seminole Field		Seminole County
Pure Oil Company			Well No. 1
Section 26-9N-6E Indian		Wilcox Sand	4128-4129 ft.

Specific gravity, 0.826
Per cent sulphur, 0.38
Saybolt Universal viscosity at 70°F., 41 sec.
Saybolt Universal viscosity at 100°F., 38 sec.
A.P.I. gravity 39.8°
Per cent water, nil
Pour point below 5°F.
Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 734 mm. First Drop: 27°C. (81°F.)

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F	Cloud test, °F	Temperature °F.
Up to 50	3.4	3.4)					Up to 122
50 - 75	5.1	8.5)	0.664	81.6			122 - 167
75 - 100	6.3	14.8	.712	67.2			167 - 212
100 - 125	7.3	22.1	.737	60.5			212 - 257
125 - 150	7.3	29.4	.759	54.9			257 - 302
150 - 175	5.3	34.7	.780	49.9			302 - 347
175 - 200	5.4	40.1	.796	46.3			347 - 392
200 - 225	5.4	45.5	.814	42.3			392 - 437
225 - 250	4.9	50.4	.828	39.4			437 - 482
250 - 275	5.5	55.9	.841	36.8			482 - 527

Vacuum distillation at 40 mm.

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F	Cloud test, °F	Temperature °F.
Up to 200	3.1	3.1	.846	35.8	41	10	Up to 392
200 - 225	4.6	7.7	.851	34.8	47	30	392 - 437
225 - 250	4.7	12.4	.867	31.7	60	50	437 - 482
250 - 275	3.8	16.2	.883	28.8	89	65	482 - 527
275 - 300	4.8	21.0	.890	27.5	165	85	527 - 572

Carbon residue of residuum 7.7%. Carbon residue of crude 1.7%.

APPROXIMATE SUMMARY

	Per cent	Sp.gr.	°A.P.I.	Viscosity
Light gasoline	14.8	0.684	75.4	
Total gasoline and naphtha	40.1	.735	61.0	
Kerosene distillate	5.4	.814	42.3	
Gas oil	17.0	.841	36.8	
Nonviscous lubricating distillate	8.4	.855- .884	34.0-28.6	50-100
Medium lubricating distillate	6.0	.834- .894	28.6-26.8	100-200
Viscous lubricating distillate	--	- -	- -	Above 200
Residuum	21.9	.958	16.2	
Distillation loss	1.2	- -	- -	

Sample Number 27240

Oklahoma	Bowlegs Field	Seminole County
I. T. I. O. Company		B. F. Davis Well No. 1
Section 13-8-6-Indian		Wilcox Sand 4,194 - 4,200 ft.
Specific gravity, 0.834		A.P.I. gravity, 38.2°
Per cent sulphur, 0.31		Per cent water, nil
Saybolt Universal viscosity at 70°F., 45 sec.		Pour point below 5°F.
Saybolt Universal viscocity at 100°F., 43 sec.		Color - green.

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 746 mm. First Drop: 28°C. (82°F.)

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	2.3	2.3)					Up to 122
50 - 75	3.2	5.5)	0.661	82.6			122 - 167
75 - 100	6.7	12.2	.706	68.9			167 - 212
100 - 125	7.7	19.9	.734	61.3			212 - 257
125 - 150	5.9	25.8	.755	55.9			257 - 302
150 - 175	6.0	31.8	.774	51.3			302 - 347
175 - 200	5.3	37.1	.792	47.2			347 - 392
200 - 225	5.4	42.5	.810	43.2			392 - 437
225 - 250	5.4	47.9	.824	40.2			437 - 482
250 - 275	5.8	53.7	.838	37.4			482 - 527

Vacuum distillation at 40 mm.

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	2.9	2.9	.859	33.2	41	5	Up to 392
200 - 225	5.1	8.0	.863	32.5	46	20	392 - 437
225 - 250	4.7	12.7	.881	29.1	58	45	437 - 482
250 - 275	4.4	17.1	.892	27.1	87	60	482 - 527
275 - 300	5.1	22.2	.903	25.2	165	80	527 - 572

Residuum 23.9%. Distillation loss 0.2%.

Carbon residue of residuum 6.8%. Carbon residue of crude 1.6%.

APPROXIMATE SUMMARY

	Per cent	Sp.gr.	°A.P.I.	Viscosity
Light gasoline	12.2	0.686	74.8	
Total gasoline and naphtha	37.1	.736	60.8	
Kerosene distillate	10.8	.817	41.7	
Gas oil	13.0	.852	34.6	
Nonviscous lubricating distillate	8.5	.869- .894	31.3-26.8	50-100
Medium lubricating distillate	6.5	.894- .908	26.8-24.3	100-200
Viscous lubricating distillate	--	- -	- -	Above 200
Residuum	23.9	.952	17.1	
Distillation loss	0.2	- -	- -	

Sample Number 27343

Oklahoma Bowlegs Field Seminole County
I. T. I. O. Co. L. Walker Well No. 1
Section 15-8N-6E Indian Wilcox Sand 4111-4134 ft.
Specific gravity, 0.821 A.P.I. gravity, 40.9°
Per cent sulphur, 0.30 Per cent water, nil
Saybolt Universal viscosity at 70°F., 40 sec. Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 38 sec. Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 740 mm. First drop: 29°C. (84°F.)

Temperature °C	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	°A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F
Up to 50	3.0	3.0)	0.653	85.2			Up to 122
50 - 75	4.3	7.3)					122 - 167
75 - 100	5.8	13.1	.698	71.2			167 - 212
100 - 125	8.4	21.5	.727	63.1			212 - 257
125 - 150	6.5	28.0	.752	56.7			257 - 302
150 - 175	5.7	33.7	.772	51.8			302 - 347
175 - 200	5.4	39.1	.790	47.6			347 - 392
200 - 225	4.5	43.6	.809	43.4			392 - 437
225 - 250	5.0	48.6	.823	40.4			437 - 482
250 - 275	5.4	54.0	.837	37.6			482 - 527

Vacuum distillation at 40 mm.

Temperature °C	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	°A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F
Up to 200	2.8	2.8	.861	32.8	40	10	Up to 392
200 - 225	4.9	7.7	.863	32.5	47	25	392 - 437
225 - 250	4.5	12.2	.868	31.5	60	45	437 - 482
250 - 275	3.8	16.0	.896	26.4	93	65	482 - 527
275 - 300	4.8	20.8	.906	24.7	175	80	527 - 572

Carbon residue of residuum 6.8%. Carbon residue of crude 1.5%.

APPROXIMATE SUMMARY

	Per cent	Sp.Gr.	°A.P.I.	Viscosity
Light gasoline	13.1	0.673	78.8	
Total gasoline and naphtha	39.1	.728	62.9	
Kerosene distillate	9.5	.816	41.9	
Gas oil	11.8	.851	34.8	
Nonviscous lubricating distillate	8.1	.864- .897	32.3-26.3	50-100
Medium lubricating distillate	6.3	.897- .911	26.3-23.8	100-200
Viscous lubricating distillate	--	- -	- -	Above 200
Residuum	21.5	.953	17.0	
Distillation loss	3.7	- -	- -	

Sample Number 27337

Oklahoma Earlsboro Field Seminole County
Prairie Oil and Gas Company Well No. 1
Section 24-9N-5E Indian Wilcox Sand 4230-4234 ft.
Specific gravity, 0.810 A.P.I. gravity, 43.2°
Per cent sulphur, 0.31 Per cent water, nil.
Saybolt Universal viscosity at 70°F., 38 sec. Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 37 sec. Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 735 mm. First Drop: 24°C. (75°F.)

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 50	6.0	6.0	0.635	91.3			Up to 122
50 - 75	4.2	10.2	.671	79.4			122 - 167
75 - 100	6.6	16.8	.709	68.1			167 - 212
100 - 125	7.8	24.6	.736	60.8			212 - 257
125 - 150	6.2	30.8	.757	55.4			257 - 302
150 - 175	6.1	36.9	.778	50.4			302 - 347
175 - 200	4.4	41.3	.795	46.5			347 - 392
200 - 225	5.2	46.5	.812	42.8			392 - 437
225 - 250	4.8	51.3	.827	39.6			437 - 482
250 - 275	5.1	56.4	.841	36.8			482 - 527

Vacuum distillation at 40 mm.

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 200	2.9	2.9	.846	35.8	41	10	Up to 392
200 - 225	4.5	7.4	.852	34.6	47	30	392 - 437
225 - 250	4.5	11.9	.868	31.5	61	50	437 - 482
250 - 275	3.6	15.5	.882	28.9	95	70	482 - 527
275 - 300	4.1	19.6	.891	27.3	185	80	527 - 572

Carbon residue of residuum 6.1%. Carbon residue of crude 1.2%.

APPROXIMATE SUMMARY

	Per cent	Sp.gr.	°A.P.I.	Viscosity
Light gasoline	16.8	0.673	78.8	
Total gasoline and naphtha	41.3	.726	63.4	
Kerosene distillate	5.2	.812	42.8	
Gas oil	16.1	.840	37.0	
Nonviscous lubricating distillate	7.8	.853-.883	34.4-28.8	50-100
Medium lubricating distillate	5.6	.883-.895	28.8-26.6	100-200
Viscous lubricating distillate	--	- -	- -	Above 200
Residuum	19.0	.955	16.7	
Distillation loss	5.0	- -	- -	

Sample Number 27236

Oklahoma	Earlsboro Field	Seminole County
Amerada Petroleum Company		F. Anderson Well No. 2
Section 15-9-5-Indian		Wilcox Sand 4,257-4,283 ft.

Specific gravity, 0.827
A.P.I. gravity, 39.6°
Per cent sulphur, 0.30
Per cent water, nil
Saybolt Universal viscosity at 70°F., 47 sec.
Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 46 sec.
Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation   Barometer 734 mm.   First Drop: 27°C. (81°F.)

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity 100°F.	Cloud Test °F	Temperature °F.
Up to 50	4.2	4.2	0.643	88.6			Up to 122
50 - 75	3.6	7.8	.672	79.1			122 - 167
75 - 100	4.2	12.0	.708	68.4			167 - 212
100 - 125	6.5	18.5	.733	61.5			212 - 257
125 - 150	5.5	24.0	.753	56.4			257 - 302
150 - 175	5.2	29.2	.772	51.8			302 - 347
175 - 200	4.9	34.1	.788	48.1			347 - 392
200 - 225	4.9	39.0	.805	44.3			392 - 437
225 - 250	5.1	44.1	.820	41.1			437 - 482
250 - 275	5.0	49.1	.834	38.2			482 - 527

Vacuum distillation at 40 mm.

Temperature °C	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity 100°F.	Cloud Test °F	Temperature °F.
Up to 200	2.3	2.3	.856	33.8	42	10	Up to 392
200 - 225	5.1	7.4	.859	33.2	46	20	392 - 437
225 - 250	4.9	12.3	.876	30.0	58	45	437 - 482
250 - 275	4.6	16.9	.885	28.4	89	65	482 - 527
275 - 300	4.5	21.4	.900	25.7	165	75	527 - 572

Residuum 26.6%.   Distillation loss 2.9%.

Carbon residue of residuum 5.5%.   Carbon residue of crude 1.5%.

APPROXIMATE SUMMARY

	Per cent	Sp.gr.	°A.P.I.	Viscosity
Light gasoline	12.0	0.674	78.4	
Total gasoline and naphtha	34.1	.729	62.6	
Kerosene distillate	10.0	.812	42.8	
Gas oil	11.7	.849	35.2	
Nonviscous lubricating distillate	8.6	.865-.887	32.1-28.0	50-100
Medium lubricating distillate	6.1	.887-.907	28.0-24.5	100-200
Viscous lubricating distillate	--	- -	- -	Above 200
Residuum	26.6	.941	18.9	
Distillation loss	2.9	- -	- -	

Sample Number 27377

Oklahoma Searight Field Seminole County
Carter Oil Co. G. W. Frasier Well #4
Section 3-9N-6E Indian Wilcox Sand 4,502 - 4,508 ft.
Specific gravity, 0.837 A.P.I. gravity, 37.6°
Per cent sulphur, 0.35 Per cent water, nil
Saybolt Universal viscosity at 70°F., 47 sec. Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 45 sec. Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 733 mm. First Drop: 31°C. (88°F.)

Temperature °C	Per Cent Cut	Sum Per Cent	Sp.gr. Cut	A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 50	1.6	1.6	0.645	87.9			Up to 122
50 - 75	2.6	4.2	.668	80.3			122 - 167
75 - 100	5.6	9.8	.707	68.6			167 - 212
100 - 125	7.5	17.3	.732	61.8			212 - 257
125 - 150	6.5	23.8	.755	55.9			257 - 302
150 - 175	5.9	29.7	.775	51.1			302 - 347
175 - 200	5.0	34.7	.790	47.6			347 - 392
200 - 225	5.2	39.9	.807	43.8			392 - 437
225 - 250	5.2	45.1	.821	40.9			437 - 482
250 - 275	5.9	51.0	.835	38.0			482 - 527

Vacuum distillation at 40 mm.

Temperature °C	Per Cent Cut	Sum Per Cent	Sp.gr. Cut	A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 200	3.6	3.6	.856	33.8	41	10	Up to 392
200 - 225	5.6	9.2	.862	32.7	47	25	392 - 437
225 - 250	5.2	14.4	.879	29.5	62	50	437 - 482
250 - 275	4.3	18.7	.891	27.3	99	65	482 - 527
275 - 300	4.4	23.1	.903	25.2	180	80	527 - 572

Carbon residue of residuum 6.5%. Carbon residue of crude 1.6%.

APPROXIMATE SUMMARY

	Per cent	Sp.Gr.	A.P.I.	Viscosity
Light gasoline	9.8	0.687	74.5	
Total gasoline and naphtha	34.7	.739	60.0	
Kerosene distillate	10.4	.814	42.3	
Gas oil	13.5	.849	35.2	
Nonviscous lubricating distillate	9.0	.866-.891	31.9-27.3	50-100
Medium lubricating distillate	5.3	.891-.906	27.3-24.7	100-200
Viscous lubricating distillate	1.2	.906-.909	24.7-24.2	Above 200
Residuum	25.3	.943	18.6	
Distillation loss	0.6	- -	- -	

Sample Number 27336

Oklahoma	Seminole Field	Seminole County
Indian Territory Illuminating Oil Co.		Stock tank
Section 24-9N-6E Indian		Hunton Lime
Specific gravity, 0.836		A.P.I. gravity, 37.8°
Per cent sulphur, 0.28		Per cent water, nil
Saybolt Universal viscosity at 70°F., 47 sec.		Pour point, below 5°F.
Saybolt Universal viscosity at 100°F., 42 sec.		Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation   Barometer 737 mm.   First Drop: 30°C. (86°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp.gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud test °F.	Temperature °F.
Up to 50°	2.7	2.7)					Up to 122
50 - 75	2.8	5.5)	0.669	80.0			122 - 167
75 - 100	4.3	9.8	.712	67.2			167 - 212
100 - 125	7.0	16.8	.735	61.0			212 - 257
125 - 150	7.0	23.8	.758	55.2			257 - 302
150 - 175	6.3	30.1	.776	50.9			302 - 347
175 - 200	5.2	35.3	.792	47.2			347 - 392
200 - 225	5.4	40.7	.809	43.4			392 - 437
225 - 250	5.9	46.6	.823	40.4			437 - 482
250 - 275	5.7	52.3	.837	37.6			482 - 527
Vacuum distillation at 40 mm.							
Up to 200	3.6	3.6	.858	33.4	41	10	Up to 392
200 - 225	5.1	8.7	.862	32.7	47	25	392 - 437
225 - 250	5.1	13.8	.880	29.3	60	45	437 - 482
250 - 275	4.9	18.7	.891	27.3	95	65	482 - 527
275 - 300	5.0	23.7	.900	25.7	180	80	527 - 572

Carbon residue of residuum 6.9%. Carbon residue of crude 1.6%.

APPROXIMATE SUMMARY

	Per cent	Sp.gr.	°A.P.I.	Viscosity
Light gasoline	9.8	0.688	74.2	
Total gasoline and naphtha	35.3	.742	59.2	
Kerosene distillate	11.3	.816	41.9	
Gas oil	13.2	.851	34.8	
Nonviscous lubricating distillate	9.1	.867-.891	31.7-27.3	50-100
Medium lubricating distillate	7.1	.891-.904	27.3-25.0	100-200
Viscous lubricating distillate	--	- -	- -	Above 200
Residuum	23.2	.951	17.3	
Distillation loss	0.8	- -	- -	

Sample Number 27381

Oklahoma Searight Field Seminole County
Sinclair Oil and Gas Co. Polly Well #2
Section 3-9N-6E Indian Hunton Lime 4,055 - 4,155 feet
Specific gravity, 0.834 A.P.I. gravity, 38.2°
Per cent sulphur, 0.24 Per cent water, trace
Saybolt Universal viscosity at 70°F., 46 sec. Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 41 sec. Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Varometer 730 mm. First Drop: 32°C. (90°F.)

Temperature °C.	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 50	1.4	1.4)					Up to 122
50 - 75	4.6	6.0)	0.671	79.4			122 - 167
75 - 100	4.3	10.3	.715	66.4			167 - 212
100 - 125	7.0	17.3	.736	60.8			212 - 257
125 - 150	7.6	24.9	.755	55.9			257 - 302
150 - 175	5.3	30.2	.775	51.1			302 - 347
175 - 200	5.8	36.0	.792	47.2			347 - 392
200 - 225	5.2	41.2	.809	43.4			392 - 437
225 - 250	5.2	46.4	.823	40.4			437 - 482
250 - 275	6.2	52.6	.836	37.8			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 200	3.4	3.4	.855	34.0	41	10	Up to 392
200 - 225	5.4	8.8	.860	33.0	48	25	392 - 437
225 - 250	4.1	12.9	.876	30.0	61	45	437 - 482
250 - 275	4.1	17.0	.887	28.0	93	60	482 - 527
275 - 300	5.3	22.3	.899	25.9	185	75	527 - 572

Carbon residue of residuum 6.0%. Carbon residue of crude 1.4%.

APPROXIMATE SUMMARY

	Per cent	Sp.Gr.	A.P.I.	Viscosity
Light gasoline	10.3	0.689	73.9	
Total gasoline and naphtha	36.0	.741	59.5	
Kerosene distillate	10.4	.816	41.9	
Gas oil	13.1	.848	35.4	
Nonviscous lubricating distillate	8.4	.863-.888	32.5-27.9	50-100
Medium lubricating distillate	5.1	.888-.901	27.9-25.6	100-200
Viscous lubricating distillate	1.9	.901-.906	25.6-24.7	Above 200
Residuum	23.6	.945	18.2	
Distillation loss	1.5	- -	- -	

Sample Number 27378

Oklahoma	Searight Field	Seminole County
Carter Oil Co.		B. O. Kiker Well #1
Section 2-9N-6E Indian	Earlsboro Sand	3,534 - 3,570 feet
Specific gravity, 0.833		A.P.I. gravity, 38.4°
Per cent sulphur, 0.20		Per cent water, nil
Saybolt Universal viscosity at 70°F., 46 sec.		Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 44 sec.		Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 733 mm. First Drop: 34°C. (93°F.)

Temperature °C.	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 50	1.7	1.7	0.645	87.9			Up to 122
50 - 75	3.3	5.0	.666	81.0			122 - 167
75 - 100	6.3	11.3	.707	68.6			167 - 212
100 - 125	7.3	18.6	.734	61.3			212 - 257
125 - 150	6.3	24.9	.755	55.9			257 - 302
150 - 175	6.2	31.1	.775	51.1			302 - 347
175 - 200	4.7	35.8	.790	47.6			347 - 392
200 - 225	5.5	41.3	.807	43.8			392 - 437
225 - 250	5.2	46.5	.821	40.9			437 - 482
250 - 275	6.0	52.5	.834	38.2			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 200	3.6	3.6	.855	34.0	41	15	Up to 392
200 - 225	5.6	9.2	.860	33.0	48	25	392 - 437
225 - 250	5.1	14.3	.877	29.9	63	45	437 - 482
250 - 275	4.6	18.9	.888	27.9	100	60	482 - 527
275 - 300	4.6	23.5	.900	25.7	195	80	527 - 572

Carbon residue of residuum 5.3%. Carbon residue of crude 1.3%.

APPROXIMATE SUMMARY

	Per cent	Sp.Gr.	A.P.I.	Viscosity
Light gasoline	11.3	0.636	74.8	
Total gasoline and naphtha	35.8	.737	60.5	
Kerosene distillate	10.7	.814	42.3	
Gas oil	13.2	.847	35.6	
Nonviscous lubricating distillate	9.4	.862-.888	32.7-27.9	50-100
Medium lubricating distillate	4.9	.888-.901	27.9-25.6	100-200
Viscous lubricating distillate	2.0	.901-.906	25.6-24.7	Above 200
Residuum	24.0	.941	18.9	
Distillation loss	0.0	- -	- -	

Sample Number 27379

Oklahoma	Earlsboro Field	Seminole County
Magnolia Petroleum Co.		Seay Well #1.
Section 12-9N-5E Indian	Earlsboro Sand	3,417 - 3,460 feet.
Specific gravity, 0.824		A.P.I. gravity 40.2°
Per cent sulphur, 0.25		Per cent water, nil
Saybolt Universal viscosity at 70°F., 43 sec.		Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 42 sec.		Color - green

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 734 mm. First Drop: 32°C. (90°F.)

Temperature °F.	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 50	2.9	2.9	0.641	89.3			Up to 122
50 - 75	4.1	7.0	.663	81.9			122 - 167
75 - 100	6.2	13.2	.702	70.1			167 - 212
100 - 125	7.1	20.3	.730	62.3			212 - 257
125 - 150	6.3	26.6	.750	57.2			257 - 302
150 - 175	5.7	32.3	.769	52.5			302 - 347
175 - 200	5.6	37.9	.787	48.3			347 - 392
200 - 225	4.8	42.7	.804	44.5			392 - 437
225 - 250	5.3	48.0	.819	41.3			437 - 482
250 - 275	5.8	53.8	.833	38.4			482 - 527

Vacuum distillation at 40 mm.

Temperature °F.	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 200	3.3	3.3	.854	34.2	41	10	Up to 392
200 - 225	5.5	8.8	.860	33.0	47	25	392 - 437
225 - 250	5.2	14.0	.874	30.4	61	45	437 - 482
250 - 275	3.6	17.6	.887	28.0	95	60	482 - 527
275 - 300	5.2	22.8	.897	26.3	185	80	527 - 572

Carbon residue of residuum 5.4%. Carbon residue of crude 1.2%.

APPROXIMATE SUMMARY

	Per cent	Sp.Gr.	A.P.I.	Viscosity
Light gasoline	13.2	0.676	77.8	
Total gasoline and naphtha	37.9	.729	62.6	
Kerosene distillate	10.1	.812	42.8	
Gas oil	13.1	.847	35.6	
Nonviscous lubricating distillate	8.8	.863-.888	32.5-27.9	50-100
Medium lubricating distillate	4.9	.888-.899	27.9-25.9	100-200
Viscous lubricating distillate	1.8	.899-.903	25.9-25.2	Above 200
Residuum	22.5	.946	18.1	
Distillation loss	0.9	- -	- -	

Sample Number 27243

Oklahoma	Seiminole Field	Seminole County
T. B. Slick Oil Co.		Franks Well No. 8.
Section 35-9-6 Indian		Cromwell sand (?) 3503-3517 ft.
Specific gravity, 0.836		A.P.I. gravity, 37.8
Per cent sulphur, 0.14		Per cent water, nil
Saybolt Universal viscosity at 70°F., 52 sec.		Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 47 sec.		Color - green

DISCILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 744 mm. First drop: 29°C. (84°F.)

Temperature °C.	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	°A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 50	2.6	2.6)	0.663	81.9			Up to 122
50 - 75	2.0	4.6)					122 - 167
75 - 100	5.7	10.3	.717	65.9			167 - 212
100 - 125	6.9	17.2	.740	59.7			212 - 257
125 - 150	5.6	22.8	.760	54.7			257 - 302
150 - 175	5.0	27.8	.777	50.6			302 - 347
175 - 200	4.5	32.3	.791	47.4			347 - 392
200 - 225	4.6	36.9	.804	44.5			392 - 437
225 - 250	5.5	42.4	.818	41.5			437 - 482
250 - 275	6.0	48.4	.832	38.6			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per Cent Cut	Sum Per Cent	Sp.Gr. Cut	°A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 200	2.7	2.7	.853	34.4	41	5	Up to 392
200 - 225	5.5	8.2	.856	33.8	47	20	392 - 437
225 - 250	4.8	13.0	.871	31.0	61	40	437 - 482
250 - 275	4.3	17.3	.883	28.8	91	60	482 - 527
275 - 300	5.4	22.7	.894	26.8	165	80	527 - 572

Carbon residue of residuum 5.1%. Carbon residue of crude 1.4%.

APPROXIMATE SUMMARY

	Per cent	Sp.Gr.	°A.P.I.	Viscosity
Light gasoline	10.3	0.693	72.7	
Total gasoline and naphtha	32.3	.741	59.5	
Kerosene distillate	10.1	.812	42.8	
Gas oil	12.6	.844	36.2	
Nonviscous lubricating distillate	9.2	.859-.884	33.2-28.6	50-100
Medium lubricating distillate	6.9	.884-.900	28.6-25.7	100-200
Viscous lubricating distillate	--	- -	- -	Above 200
Residuum	28.2	.934	20.0	
Distillation loss	0.7	- -	- -	

Sample Number 26566

Oklahoma	Seminole Field	Seminole County
Base of Viola Limestone		4171-4256 ft.
Specific gravity, 0.844		A.P.I. gravity 36.2
Per cent sulphur, 0.47		Per cent water, nil
Saybolt Universal viscosity at 70°F., 48 sec.		Pour point below 5°F.
Saybolt Universal viscosity at 100°F., 45 sec.		Color, brownish black

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Air Distillation Barometer 747 mm. First Drop: 43°C. (109°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp.Gr. of cut	°A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 50							Up to 122
50 - 75	1.8	1.8)					122 - 167
75 - 100	5.6	7.4)	0.713	67.0			167 - 212
100 - 125	7.7	15.1	.735	61.0			212 - 257
125 - 150	6.6	21.7	.755	55.9			257 - 302
150 - 175	6.5	28.2	.774	51.3			302 - 347
175 - 200	6.5	34.7	.793	46.9			347 - 392
200 - 225	5.7	40.4	.809	43.4			392 - 437
225 - 250	5.9	46.3	.825	40.0			437 - 482
250 - 275	6.1	52.4	.839	37.2			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp.Gr. of cut	°A.P.I. Cut	Viscosity at 100°F.	Cloud Test °F.	Temperature °F.
Up to 200	3.9	3.9	.867	31.7	42	28	Up to 392
200 - 225	4.8	8.7	.872	30.8	47	50	392 - 437
225 - 250	5.7	14.4	.887	28.0	60	65	437 - 482
250 - 275	4.0	18.4	.904	25.0	91	78	482 - 527
275 - 300	5.7	24.1	.921	22.1	168	92	527 - 572

Carbon residue of residuum 10.5%. Carbon residue of crude 2.4%.

APPROXIMATE SUMMARY

	Per cent	Sp.Gr.	°A.P.I.	Viscosity
Light gasoline	7.4	0.713	67.0	
Total gasoline and naphtha	34.7	.752	56.7	
Kerosene distillate	11.6	.817	41.7	
Gas oil	13.8	.856	33.8	
Nonviscous lubricating distillate	9.3	.876-.906	30.0-24.7	50-100
Medium lubricating distillate	6.2	.906-.928	24.7-21.0	100-200
Viscous lubricating distillate	0.9	.928-.931	21.0-20.5	Above 200
Residuum	23.2	.963	15.4	
Distillation loss	0.3	- -	- -	

Serial No. 2825
August, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

COAL-MINE FATALITIES IN JULY, 1927

By W. W. Adams[1]

Accidents at all coal mines in the United States during the month of July, 1927, resulted in the death of 135 men, according to reports of State mine inspectors to the United States Bureau of Mines, Department of Commerce. Of this number 108 deaths occurred at bituminous mines and 27 at anthracite mines. The production of both bituminous and anthracite coal in the month was 38,597,000 tons - 33,563,000 tons of bituminous and 5,034,000 tons of anthracite. Fatality rates based on these figures were 3.22 and 5.36, respectively, per million tons, while the industry as a whole showed a rate of 3.50.

Reports of accidents during the first seven months of 1927 show that 1,305 men lost their lives in the mining industry; 1,008 at bituminous mines and 297 at anthracite mines. The output of coal during these months was 310,190,000 tons of bituminous and 45,935,000 tons of anthracite. For this period the fatality rates were 3.25 for bituminous, 6.47 for anthracite and 3.66 for the entire industry.

A comparison of July of this year with July, 1926 shows a reduction of 26 deaths in bituminous mines, and 34 in the anthracite mines, a total reduction of 60. Owing to the present idleness of many mines the July production has also decreased from 43,472,000 tons to 33,563,000 tons of bituminous and from 8,427,000 tons to 5,034,000 tons of anthracite. The fatality rates for July 1926 were 3.08 for bituminous mines, 7.24 for anthracite mines and 3.76 for both classes of mines combined. These figures show that in July of the present year the coal industry's fatality was lower than in July last year, the reduction being due to a notable lowering of the fatality rate at anthracite mines which more than counterbalanced a slight increase in the death rate at bituminous mines.

The month of July was free from major disasters, that is, accidents causing the death of five or more men. The same was true for June. Thus far in 1927 seven major disasters have occurred and have caused the loss of 140 lives. During the same period in 1926 there were ten major disasters which resulted in the death of 210 men. Based exclusively on these disasters the fatality rates per million tons of coal produced were 0.36 in 1927 and 0.59 in 1926.

---

[1] Statistician, Bureau of Mines, Department of Commerce.

A comparison of the principal causes of accidents during the period from January to July of the present year with the same period of 1926, shows a reduction in the death rates from falls of roof and coal, haulage, and gas or dust explosions. The rates for explosives and electricity indicate an increase. The first three causes usually account for about 80 per cent of all fatalities at coal mines. About 8 or 10 per cent are due to electricity and explosives. Comparative death rates per million tons are as follows:

	Year 1926	Jan.-July 1926	Jan.-July 1927
All causes	3.790	3.897	3.664
Falls of roof and coal	1.829	1.842	1.735
Haulage	.650	.694	.587
Gas or dust explosions:			
Local explosions	.111	.127	.163
Major explosions	.525	.590	.356
Explosives	.145	.138	.202
Electricity	.143	.135	.177

Tables 1 to 5 inclusive, present a detailed statistical comparison of the number and causes of accidents and corresponding rates in 1927 with similar figures for earlier years. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE 1 - NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES

	Year 1926	Jan.-July 1926	Jan.-July 1927
Falls of Roof & Coal........................	1.829	1.842	1.735
At face	1.386	1.440	1.306
In room	.238	.222	.222
On entry	.193	.177	.199
On slope	.012	.003	.008
Haulage	.650	.694	.587
Switching and spragging	.020	.022	.006
Coupling	.008	.008	.023
Falling from trips	.030	.020	.036
Run over	.241	.247	.239
Caught between car and rib	.136	.138	.146
Caught between car and roof	.027	.031	.030
Runaway cars	.057	.042	.059
Miscellaneous	.131	.186	.048
Gas or Dust Explosions	.636	.717	.519
Open light	.191	.099	.090
Defective safety lamp	.005	.008	- -
Electric arc	.081	014	.025
Shot	.077	.135	.033
Powder explosion	.005	.008	.003
Miscellaneous	.277	.453	.368
Explosives	.145	.138	.202
Transportation	---	---	.003
Charging	.006	.011	.006
Suffocation	.008	.006	---
Drilling into old holes	.003	.003	---
Striking in loose rocks	---	---	---
Thawing	---	---	---
Caps & detonators	.001	.003	.008
Unguarded shots	.006	.006	.008
Returned too soon	.013	.014	.011
Premature shot	.048	.034	.070
Sparks from lamp, etc.	.005	.008	.008
Delayed shots	.015	.014	.017
Shot breaking through rib	.011	.011	.023
Miscellaneous	.029	.028	.048
Electricity	.143	.135	.177
Direct contact with trolley wire	.050	.031	.067
Tools striking trolley wire	.003	.006	.003
Contact with mining machine	.013	.006	.017
Contact with machine feed wire	.009	.011	.025
Contact with haulage motor	.003	---	---
Miscellaneous	.065	.081	.065

TABLE 2 - COAL-MINE FATALITIES DURING JULY, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																													
Falls of roof.........	7	-	1	-	-	-	-	-	7	-	-	-	-	-	-	2	-	12	-	1	-	1	-	-	20	-	51	10	61
Falls of side.........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	2	-	5	2	7
Haulage...............	3	-	-	1	-	-	-	-	5	1	-	-	-	-	-	-	-	5	-	1	-	-	-	-	6	1	23	4	27
Gas or dust explosions.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	3	2	5
Explosives............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2	-	4	4	8
Suffocated by mines gases	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electricity...........	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	1	1	3	-	1	-	-	-	1	3	-	14	1	15
Animals...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mining machines........	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3	-	3
Mine fires............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes..........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
TOTAL..........	11	-	1	1	-	-	-	-	16	1	-	-	-	-	-	5	3	23	-	3	-	1	-	1	36	1	103	24	127
SHAFT																													
Persons falling.......	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Objects falling........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Cages, skips..........	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
Other causes..........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL..........	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	4
SURFACE																													
Mine cars.............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electricity...........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1
Machinery.............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boiler explosions......	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Railway cars..........	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	3	-	3
Other causes..........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL..........	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	4	-	4
GRAND TOTAL, July, 1927	11	0	1	1	0	1	0	0	17	1	0	0	0	0	0	5	3	24	0	3	0	1	0	1	38	1	108	27	135
GRAND TOTAL, July, 1926	23	1	0	2	10	0	1	1	16	0	0	1	0	1	0	2	1	24	0	0	0	1	5	1	40	4	134	61	195

TABLE 3 - COAL-MINE FATALITIES DURING 1927 and 1926, BY MONTHS AND STATES

MONTH	Ala	Alas	Ark	Col	Ga. & N.C.	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January..............,	6	-	2	8	-	19	3	1	-	23	-	1	1	1	2	-	7	2	35	-	3	-	1	2	1	43	4	165	45	210
February.............	7	-	2	5	-	11	6	1	2	10	-	-	-	1	1	2	9	2	30	-	-	-	5	5	2	35	-	136	41	177
March................	6	-	-	7	-	23	7	1	2	6	-	-	-	-	2	-	6	2	35	-	3	-	2	3	1	38	1	145	41	186
April................	6	-	-	2	-	4	-	2	-	2	-	1	-	1	-	-	3	2	33	-	1	-	3	3	7	144	-	214	40	254
May..................	6	-	1	8	-	4	-	1	-	11	-	-	-	-	1	-	5	1	25	-	-	-	3	9	2	50	2	129	53	182
June.................	4	-	1	3	-	-	2	-	1	5	1	-	-	2	3	-	3	2	29	-	-	-	2	1	1	49	2	111	50	161
July.................	11	-	1	1	-	-	1	-	-	17	1	-	-	-	-	-	5	3	24	-	3	-	1	-	1	38	1	108	27	135
TOTAL, 7 months, 1927	46	0	7	34	0	61	19	6	5	74	2	2	1	5	9	2	38	14	211	0	10	0	17	23	15	397	10	1,008	297	1,305
TOTAL, 7 months, 1926	93	1	2	30	1	81	20	4	11	106	6	1	2	2	9	0	45	101	213	0	15	0	10	29	5	342	16	1,145	241	1,386
TOTAL, 1926.....	139	1	7	53	3	166	78	16	17	178	12	1	9	5	13	1	80	124	420	0	50	0	20	58	15	573	22	2,061	453	2,514

TABLE 4 - AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED

Cause of accident	Per cent of total 1917-1926	Death rates per million short tons: Average for 10 years 1917-1926	Year 1925	Year 1926	Average for July 10 years 1917-1926	1927 June	1927 July	1926 July
				Bituminous Mines				
1. Falls of roof and coal	48.96	1.759	1.750	1.717	1.869	1.720	1.668	1.449
2. Underground haulage	18.18	.653	.586	.655	.726	.382	.685	.897
3. Explosions of gas or coal dust:								
Local explosions	2.91	.104	.112	.080	.077	.164	.090	.023
Major explosions	10.84	.390	.469	.565	.109	---	---	.207
4. Explosives	3.30	.118	.094	.080	.127	.246	.119	.046
5. Electricity	4.01	.144	.154	.161	.234	.164	.417	.230
6. Mining machines	1.33	.048	.067	.045	.045	.027	.090	---
7. Other causes underground	2.93	.105	.089	.067	.082	.082	---	---
8. All causes underground	92.46	3.321	3.321	3.370	3.269	2.785	3.069	2.852
9. All shaft accidents	1.73	.062	.058	.047	.060	.027	.030	.023
10. All accidents on surface	5.81	.209	.148	.147	.281	.219	.119	.207
11. All accidents.	100.00	3.592	3.527	3.564	3.610	3.031	3.218	3.082
				Anthracite Mines				
1. Falls of roof and coal	42.71	2.496	2.750	2.588	2.850	3.858	2.383	2.611
2. Underground haulage	12.75	.745	.906	.612	.797	.413	.795	.949
3. Explosions of gas:								
Local explosions	6.71	.392	.421	.329	.392	.689	.397	.237
Major explosions	1.51	.088	.275	.247	.202	---	---	.831
4. Explosives	12.37	.723	.857	.588	.783	.827	.795	.949
5. Electricity	1.00	.059	.065	.024	.094	.138	.199	.119
6. Other causes underground	8.18	.478	.323	.459	.554	.689	.199	.949
7. All causes underground	85.23	4.981	5.597	4.847	5.672	6.614	4.768	6.645
8. All shaft accidents	2.30	.134	.065	.094	.149	---	.596	.119
9. All accidents on surface	12.47	.729	.809	.388	.851	.276	---	.475
10. All accidents	100.00	5.844	6.471	5.329	6.672	6.890	5.364	7.239

TABLE 5 - COAL-MINE FATALITIES, BY CAUSES, DURING THE CALENDAR YEAR 1926, AND THE FIRST SEVEN MONTHS OF 1927.

Cause of accident	1926			Jan.-July, 1927		
	Bituminous	Anthracite	Total	Bituminous	Anthracite	Total
Falls of roof and coal..........	993	220	1,213	481	137	618
Underground haulage.............	379	52	431	178	31	209
Explosions of gas or coal dust...	373	49	422	148	37	185
Explosives......................	46	50	96	36	36	72
Electricity.....................	93	2	95	58	5	63
Others underground..............	65	39	104	46	30	76
Shaft...........................	27	8	35	9	4	13
Surface.........................	85	33	118	52	17	69
Total...........................	2,061	453	2,514	1,008	297	1,305

rial No. 2826.
ugust, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

CONSUMPTION OF EXPLOSIVES IN JULY, 1927.

By W. W. Adams [1]

Sales of explosives in the United States in July, 1927, amounted to 345,200 kegs (8,630,000 pounds) of black blasting powder, 4,403,000 pounds of permissible explosives, and 26,046,000 pounds of high explosives other than permissibles. These figures are based upon reports from manufacturing companies to the United States Bureau of Mines, Department of Commerce, and they include an estimate of sales by several companies that do not report monthly. Reports actually received from the manufacturers covered sales of 338,318 kegs of powder, 4,396,681 pounds of permissibles, and 24,473,027 pounds of other high explosives. The sales of black powder in July were larger than in the previous month but considerably smaller than in July 1926. The permissibles sold in July 1927 were smaller in volume than in June and also smaller than in July a year ago. Sales of other high explosives in July were also smaller in volume than in the preceding month and in July last year.

PERMISSIBLE EXPLOSIVES: Sales of permissible explosives during the first seven months of 1927 amounted to 36,594,000 pounds, including an estimate of sales by several non-reporting companies. The current year's sales represent an increase of five per cent over the corresponding seven months of 1926. About 96 per cent of the permissibles sold thus far in 1927 have been for use in coal-mining operations(66.9 per cent for bituminous coal mining and 28.9 per cent for anthracite mining). The small remainder was used for other mining, quarrying, construction work, and various other purposes. In the bituminous coal-mining industry the amount of all classes of explosives during the first seven months of 1927 has averaged 264 pounds for each thousand tons of coal produced; of this average quantity, 79 pounds (30 per cent) were explosives of permissible types. Corresponding records for anthracite mines show a seven-month average consumption of 751 pounds of all kinds of explosives per thousand tons of coal, of which quantity 230 pounds (30 per cent) were permissibles. The consumption of permissible explosives for coal mining and for all other purposes since the first of January of the current year has exceeded a million pounds in each of the following States: Pennsylvania, West Virginia, Alabama, Kentucky, and Illinois. These five States have used more than 32 million pounds of permissible explosives during the past seven months, about 89 per cent of the total quantity used in all States. The States named are among the largest coal-producing States, hence the large consumption of permissible explosives which are manufactured mainly for use in coal mines.

---

[1] Statistician, Bureau of Mines, Department of Commerce.

102

BLACK BLASTING POWDER: Manufacturers' reports covering sales of black blasting powder sold during the first seven months of 1927 indicate a total of 2,888,000 kegs (72,200,000 pounds), a reduction of 13 per cent from the quantity sold during the corresponding months of 1926. More than 84 per cent of the powder was sold for use in coal mines (72.9 per cent for bituminous mines and 11.3 per cent for anthracite mines). About 2 per cent was used in metal mines, 5 per cent in quarries, 5 per cent in construction work, and 4 per cent for miscellaneous purposes. During the past seven months the consumption at bituminous coal mines has averaged 170 pounds out of an average of 264 pounds of all classes of explosives for each thousand tons of coal produced, indicating that black powder constituted 64 per cent of all explosives used at bituminous coal mines during the seven months mentioned. The anthracite mining industry has averaged 178 pounds (24 per cent) of black powder out of an average consumption of 751 pounds of all kinds of explosives per thousand tons of coal mined. Each of the following States has used more than 100,000 kegs (25 pounds per keg) of black powder for mining and for all other purposes since the beginning of the present year: Pennsylvania, Kentucky, West Virginia, Illinois, Indiana, Ohio, and Kansas, the total consumption in these seven States being more than two million pounds, or 74 per cent of the total amount used in all States.

OTHER HIGH EXPLOSIVES: The July sales of high explosives other than permissibles brought the total sales of this class of explosives during the first seven months of 1927 to 173,163,000 pounds, almost identical with the quantity sold during the first seven months of last year. The indicated sales in 1927 include 167,401,586 pounds actually reported and an estimate of sales by several companies that do not furnish monthly reports to the Bureau of Mines. The metal-mining industry was the largest consumer of this class of explosives, the quantity used during the past seven months amounting to 30.9 per cent of the total quantity used for all purposes; coal mines used 11.5 per cent (8.8 per cent for anthracite mines and 2.7 per cent for bituminous coal mines); quarries and nonmetallic mineral mines used 28.4 per cent; railway and other construction work 15.9 per cent; and miscellaneous purposes 13.3 per cent. Consumption of all classes of explosives at bituminous coal mines during the first seven months of 1927 has averaged 264 pounds per thousand tons of coal produced; of this quantity 6 per cent (15 pounds) was high explosives other than permissibles. Similar records for anthracite mines, indicating an average consumption of 751 pounds of all kinds of explosives per thousand tons of coal, show that 46 per cent (343 pounds) were high explosives other than permissibles. The largest quantities of this class of explosives sold since January first were used in the States of Pennsylvania, Michigan, California, New York, Minnesota, Ohio, Oklahoma, Florida, Missouri, Texas, and Alabama, in the order named. Each of these States used more than half a million pounds and their aggregate consumption amounted to 101 million pounds, about 60 per cent of the total quantity used in all States during the first seven months of 1927. The principal consumers of these explosives in the States mentioned were: Anthracite mining and stone quarrying in Pennsylvania; metal mining in Michigan, Minnesota, Oklahoma, Alabama, and Missouri; construction work in California and Florida; quarrying and nonmetallic mineral mining in New York and Ohio; and construction work, quarrying and nonmetallic mineral mining in Texas.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in July were more than 268,200 kegs, showed that the mills were operated to 37 per cent of their capacity in July as compared with 40 per cent in June, 29 per cent in May, and 35 per cent in July last year. The amount of explosives remaining on hand at the close of July represented 53 per cent of one month's manufacturing capacity of the mills reporting, as compared with 45 per cent at the close of July a year ago.

	July, 1926	July, 1927	Jan.-July, 1927
Capacity (Kegs)	953,583	796,083	5,572,581
Manufactured	333,542	294,963	2,238,161
Per cent of capacity	35	37	40
Shipments	321,967	289,269	2,225,873
Per cent of capacity	34	36	40
Sales	331,025	268,297	2,158,457
Per cent of capacity	35	34	39
Stocks, end of month	431,493	418,675	418,675
Per cent of capacity	45	53	7.5

The following percentage figures show the extent of capacity to which mills manufacturing black powder were operated in 1924, 1925, 1926, and in the months of January to July, 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month.

	Manufactured	Shipments	Sales	Stocks
Year 1924	41	41	41	3.8
Year 1925	38	39	38	3.2
Year 1926	40	40	39	3.6
Average, 7 mos. 1926	37	36	36	6.5
1927				
January	54	55	56	50
February	54	47	45	58
March	36	36	38	58
April	31	32	30	57
May	29	36	35	49
June	40	37	33	52
July	37	36	34	53
Average, 7 months ...	40	40	39	7.5

Reports from 23 mills that sold more than 23 million pounds of permissibles and other high explosives in July showed that the mills were operated to 58 per cent of their capacity in July as compared with 65 per cent in June, 73 per cent in May, and 67 per cent in July last year. The amount of explosives remaining on hand at the close of July represented 15 per cent of one month's manufacturing capacity of the mills reporting, as compared with 13 per cent at the close of July a year ago.

	July, 1926	July, 1927	Jan.-July, 1927
Capacity (Pounds).......	39,153,332	40,945,000	275,865,000
Manufactured...........	26,324,723	23,579,665	176,670,029
Per cent of capacity....	67	58	64
Shipments..............	26,923,431	23,904,231	176,952,754
Per cent of capacity....	69	58	64
Sales..................	26,633,041	23,628,050	170,338,952
Per cent of capacity....	68	58	62
Stocks, end of month....	5,283,055	6,327,582	6,327,582
Per cent of capacity....	13	15	2.3

The percentage of full-time capacity to which mills manufacturing permissibles and other explosives were operated in 1924, 1925, 1926, and in the months of January to July 1927, is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining on hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924..............	62	62	59	1.4
Year 1925..............	62	62	59	1.5
Year 1926..............	68	68	64	1.4
Average, 7 mos. 1926...	65	66	62	1.9
1927				
January................	59	58	57	19
February...............	63	62	57	20
March..................	64	64	62	20
April..................	66	69	65	17
May....................	73	72	69	18
June...................	65	66	64	17
July...................	58	58	58	15
Average, 7 months......	64	64	62	2.3

PYROTOL: During the first seven months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 9,647,810 pounds of pyrotol of which 726,850 pounds represented shipments in July. During the corresponding seven months last year the shipments amounted to 10,277,100 pounds. Most of the pyrotol shipped was for use by farmers in clearing land. Table D shows the amount of pyrotol shipped to each State in July 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal-mining operations in each State from January to July 1927 is shown in Table C. Table D shows the quantity of pyrotol distributed in July to the varibus States. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE A - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during July, 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	7,686	713,050	393,250
Alaska	65	213,100	2,000
Arizona	1,380	188,050	- - -
Arkansas	5,978	158,793	1,383
California	9,076	1,877,493	- - -
Colorado	4,812	409,090	94,400
Connecticut	78	112,900	- - -
Delaware	30 Rtd.	8,600	- - -
Florida	2,340	639,700	- - -
Georgia	2,215	169,275	- - -
Idaho	153	242,759	- - -
Illinois	6,776	722,150	42,275
Indiana	28,953	506,925	13,450
Iowa	2,877	366,050	500
Kansas	6,915	523,575	4,000
Kentucky	57,915	521,130	220,300
Louisiana	- - -	180,613	- - -
Maine	183	84,150	- - -
Maryland	1,317	136,875	18,600
Massachusetts	129	132,000	- - -
Michigan	1,802	1,738,000	1,150
Minnesota	5,624	1,185,168	- - -
Mississippi	948	140,300	- - -
Missouri	4,433	831,858	24,850
Montana	2,960	580,595	- - -
Nebraska	92	21,625	- - -
Nevada	4,200	219,700	- - -
New Hampshire	73	16,925	- - -
New Jersey	1	361,125	- - -
New Mexico	2,729	86,800	40,250
New York	1,083	1,328,250	2,300
N. Carolina	1,427	236,675	1,000
N. Dakota	29	4,225	4,000
Ohio	19,771	1,214,575	2,800
Oklahoma	8,453	832,460	36,138
Oregon	1,228	344,550	- - -
Pennsylvania	67,580	3,358,096	2,190,570
Rhode Island	- - -	25,550	- - -
S. Carolina	113	19,300	- - -
S. Dakota	21	12,335	- - -
Tennessee	11,316	329,575	31,800
Texas	5,088	955,617	- - -
Utah	856	490,495	98,250
Vermont	8	32,700	- - -
Virginia	7,864	327,575	54,390
Washington	5,230	824,375	38,000
West Virginia	43,667	512,450	1,013,325
Wisconsin	187	392,325	- - -
Wyoming	2,717	143,525	67,700
TOTAL JULY 1927	338,318	24,473,027	4,396,681

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first seven months of 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	63,137	5,068,619	2,924,250
Alaska	321	1,320,090	58,700
Arizona	12,575	1,007,975	- - -
Arkansas	31,536	849,949	74,033
California	44,135	10,731,603	- - -
Colorado	29,634	3,101,516	472,900
Connecticut	244	898,100	- - -
Delaware	- - -	50,070	- - -
Florida	14,254	6,057,422	- - -
Georgia	9,722	1,174,500	- - -
Idaho	2,675	2,414,568	8,850
Illinois	320,052	4,383,165	1,019,975
Indiana	256,729	2,163,425	284,400
Iowa	59,427	1,573,825	3,450
Kansas	101,354	4,332,326	161,765
Kentucky	388,189	2,726,955	1,923,125
Louisiana	350	1,387,984	48,750
Maine	1,122	404,575	- - -
Maryland	15,504	1,382,700	102,850
Massachusetts	1,036	713,775	- - -
Michigan	5,418	12,212,775	1,150
Minnesota	22,698	7,313,677	- - -
Mississippi	1,981	764,250	- - -
Missouri	40,431	5,697,897	100,431
Montana	28,443	3,833,117	13,850
Nebraska	1,427	111,500	- - -
Nevada	23,456	1,989,125	200
New Hampshire	293	97,100	- - -
New Jersey	57	1,909,750	- - -
New Mexico	11,697	380,775	208,300
New York	7,449	8,626,699	30,400
N. Carolina	17,859	2,248,500	5,750
N. Dakota	9,252	62,382	9,975
Ohio	145,794	6,581,670	107,400
Oklahoma	63,537	6,409,902	147,280
Oregon	12,890	2,417,975	- - -
Pennsylvania	562,753	27,062,365	18,250,115
Rhode Island	90	45,400	- - -
S. Carolina	1,764	466,050	- - -
S. Dakota	370	689,820	1,300
Tennessee	66,929	2,285,600	199,500
Texas	52,125	5,343,440	14,850
Utah	9,906	4,746,365	478,400
Vermont	2,110	269,650	- - -
Virginia	38,726	2,257,125	791,290
Washington	26,833	4,833,610	371,575
West Virginia	305,802	3,134,775	8,247,325
Wisconsin	3,327	3,058,150	50
Wyoming	15,146	809,000	477,200
TOTAL 1st 7 MOS 1927	2,830,559	167,401,586	36,539,389

(3102)

JULY, 1927

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs	Pounds	Pounds
Quantity used for:			
Coal mining................	268,668	2,376,775	4,175,401
Metal mining...............	12,927	6,440,863	1,150
Quarrying and nonmetallic mineral mining...........	17,217	7,651,962	53,550
Railway and other construction work.....................	19,830	4,884,918	58,091
All other purposes.........	19,676	3,118,509	108,489
TOTAL JULY 1927...............	338,318	24,473,027	4,396,681
JANUARY TO JULY, 1927, INCLUSIVE			
Quantity used for:			
Coal mining................	2,383,705	19,230,051	35,013,106
Metal mining...............	54,673	51,694,847	47,125
Quarrying and nonmetallic mineral mining...........	140,341	47,599,928	301,070
Railway and other construction work................	144,836	26,693,763	145,186
All other purposes.........	107,004	22,182,997	1,032,902
TOTAL 1st 7 MOS. 1927.........	2,830,559	167,401,586	36,539,389

TABLE C - Quantity of explosives sold for use in COAL MINES in July 1927
by Manufacturers rendering monthly reports.
(Including cumulative figures for the first seven months of 1927)

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama........	5,653	48,225	44,900	348,494	391,100	2,902,300
Arkansas.......	5,913	31,051	3,150	37,600	1,383	8,683
Colorado.......	4,304	21,431	15,500	113,725	89,050	433,900
Illinois.......	6,389.	316,009	21,200	197,250	42,375	937,450
Indiana........	28,434	252,157	135,600	393,050	8,750	255,700
Iowa...........	2,791	56,592	3,225	64,325	500	2,000
Kansas.........	6,562	96,828	46,450	369,976	3,700	160,215
Kentucky.......	54,753	368,262	118,850	565,750	200,850	1,738,505
Maryland.......	710	12,026	12,600	32,600	8,100	54,700
Michigan.......	1,800	3,917	2,150	27,150	- - -	- - -
Missouri.......	2,711	28,739	12,550	87,450	- - -	27,131
Montana........	960	19,863	- - -	6,250	- - -	6,850
New Mexico.....	- - -	2,805	13,250	17,600	28,500	196,050
North Dakota...	22	8,966	800	34,325	4,000	9,975
Ohio...........	15,476	124,307	21,525	264,575	250	43,000
Oklahoma.......	7,408	56,087	2,200	68,650	32,008	123,087
Penna. (Bitum.)	24,542	202,407	81,950	807,625	904,270	7,398,195
Tennessee......	10,897	56,834	7,800	91,450	31,800	192,100
Texas..........	1,020	13,323	- - -	5,700	- - -	- - -
Utah...........	- - -	- - -	6,150	33,700	96,250	469,900
Virginia.......	6,545	31,650	12,400	136,500	55,940	780,890
Washington.....	1,709	9,098	15,250	55,650	29,000	261,150
West Virginia..	41,092	289,356	89,900	561,450	973,900	7,987,525
Wyoming........	210	7,581	10,350	35,650	46,700	395,700
Other States...	330	5,015	54,050	81,475	3,000	72,600
Total (Bitum.).	230,731	2,062,529	730,800	4,437,970	2,951,426	24,457,606
Penna. (Anth.).	37,937	321,176	1,645,975	14,792,081	1,223,975	10,555,500
Grand Total as reported....	268,668	2,383,705	2,376,775	19,230,051	4,175,401	35,013,106
Est. total inc.) non-reporting) companies)	Anth.	327,800		15,750,000		10,572,000
	Bitum.	2,104,700		4,721,000		24,492,000
Total reported plus estimate..		2,432,500		20,471,000		35,064,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period July 1, 1927 to July 31, 1927.

State	State Highway Departments	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
California..........	- - -	24,000	20,000	- - -	44,000
Colorado...........	- - -	- - -	44,000	- - -	44,000
Idaho...............	- - -	- - -	20,000	- - -	20,000
Indiana.............	20,000	- - -	- - -	- - -	20,000
Iowa................	30,000	- - -	- - -	- - -	30,000
Michigan............	- - -	40,000	- - -	- - -	40,000
Minnesota...........	- - -	214,550	- - -	- - -	214,550
Mississippi.........	10,000	10,000	- - -	- - -	20,000
Oregon..............	43,850	22,050	38,000	- - -	103,900
S. Carolina.........	2,000	- - -	- - -	- - -	2,000
S. Dakota...........	30,000	28,500	- - -	- - -	58,500
Utah................	- - -	- - -	- - -	20,000	20,000
Washington..........	5,000	56,900	- - -	- - -	61,900
West Virginia.......	- - -	16,000	- - -	- - -	16,000
Wisconsin...........	- - -	32,000	- - -	- - -	32,000
Total July..........	140,850	444,000	122,000	20,000	726,850
Total June..........	225,300	685,250	108,300	72,900	1,091,750
Total May...........	162,000	825,500	26,000	352,100	1,365,600
Total April.........	281,550	1,669,550	7,500	222,000	2,180,600
Total March.........	249,500	1,916,860	- - -	108,700	2,275,060
Total February......	170,750	1,020,150	- - -	- - -	1,190,900
Total January.......	93,000	704,050	- - -	20,000	817,050
Grand Total.........	1,322,950	7,265,360	263,800	795,700	9,647,810

Serial No. 2827.
August, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

SIXTEENTH SEMI-ANNUAL MOTOR GASOLINE SURVEY

By E. C. Lane[1], D. J. Condit[2], and C. S. Luce[3].

The motor gasoline that is being marketed in the United States this summer is slightly more volatile than that sold a year ago.

During the past eight years the Bureau of Mines has made semi-annual surveys of the gaoline marketed in the United States, the survey just completed being the sixteenth in the series. The cities in which samples have been collected have been chosen as representative of the more important marketing territories as it is obviously impracticable to obtain a sample of every gasoline sold in the entire country.

A summary of the results of the sixteen surveys is given in Tables 1 and 2, the "summer" surveys being shown in Table 1, and the "winter" surveys in Table 2. Average figures for each city in which gasoline samples were collected are shown in Table 3. A study of these tables as well as of the individual analysis shows a general tendency toward the marketing of a standardized product. Although this holds for the averages of the country as a whole, there are exceptions in some localities. In Laramie, Wyoming, although there has been a decrease in volatility as compared with July, 1926, the samples are nevertheless better than the average for the entire survey. The samples collected in Bartlesville, Oklahoma, are the poorest as a whole from the standpoint of volatility, of those from any city in this survey.

Until recent years there has been a distinct difference between "summer" and "winter" gasoline; that marketed during the summer being less volatile than that sold during the winter. This summer the difference between "summer" and "winter" gasoline is shown only in the lower end of the distillation range while the upper end is more volatile. This tendency toward uniformity confirms the observation made in the fifteenth survey.

Distillation curves representing the present Federal Specification for United States motor gasoline and the average of all samples in the present survey are given in Figure 1.

The samples were tested in accordance with methods given in Bureau of Mines Technical Paper 323-A[4], and in the case of Samples from Laramie, Wyoming, and Denver, Colorado, the resulting figures were corrected for altitude. All temperatures are shown in degrees Fahrenheit.

---

[1] - Assistant petroleum chemist, Bureau of Mines, Department of Commerce.
[2] - Junior chemical engineer, Bureau of Mines.
[3] - Junior chemist, Bureau of Mines.
[4] - Federal Specifications Board, Standard Specification Number 2c, United States government specification for lubricants and liquid fuels and methods for testing, Technical Paper 323-A, Bureau of Mines, obtainable from the superintendent of Documents, Government Printing Office, Washington, D. C. for 15 cents.

TABLE I -- AVERAGE RESULTS OF MOTOR GASOLINE SURVEYS

SUMMER

Survey	Specific Gravity	A.P.I. Degrees	First Drop	20%	50%	90%	End Point	Average B.P.	Per cent Recovered
July 1920	0.749	57.4	130	208	268	388	446	277	96.7
July 1921	0.747	57.9	125	202	262	377	433	270	96.7
July 1922	0.752	56.8	121	208	270	375	429	273	96.8
July 1923	0.751	56.9	125	206	269	382	436	273	96.8
July 1924	0.751	56.9	107	200	271	390	431	273	96.0
July 1925	0.754	56.2	108	204	275	387	427	275	96.2
July 1926	0.750	57.2	100	194	266	382	421	267	96.7
July 1927	0.748	57.7	102	193	267	381	417	267	96.4
Average	0.750	57.2	115	202	269	383	430	272	96.5

TABLE 2 -- AVERAGE RESULTS OF MOTOR GASOLINE SURVEYS

WINTER

Survey	Specific Gravity	A.P.I. Degrees	First Drop	20%	50%	90%	End Point	Average B.P.	Per cent Recovered
Jan. 1920	0.748	57.7	119	200	259	369	427	264	96.6
Jan. 1921	0.744	58.7	113	197	261	377	431	264	95.9
Jan. 1922	0.745	58.4	102	200	267	377	430	268	96.0
Jan. 1923	0.744	58.8	107	201	267	375	427	268	96.0
Jan. 1924	0.748	57.7	96	196	267	383	431	268	96.2
Jan. 1925	0.746	58.2	95	195	266	382	425	267	96.2
Jan. 1926	0.747	57.9	93	189	264	380	423	264	96.3
Jan. 1927	0.748	57.7	92	185	264	383	421	264	96.5
Average	0.746	58.2	102	195	264	378	427	266	96.2

TABLE 3 -- AVERAGE RESULTS OF MOTOR GASOLINE SURVEY, JULY 1927

District	Specific Gravity	A.P.I. Degrees	First Drop	20%	50%	90%	End Point	Average B.P.	Per cent Recovered
N.Y.C.	0.744	58.7	101	195	270	376	416	268	96.6
Washington	0.759	54.9	111	198	258	373	415	264	96.9
Pittsburgh	0.751	56.9	103	191	262	379	418	265	96.4
Chicago	0.743	58.9	98	187	270	387	418	267	96.3
New Orleans	0.745	58.4	104	191	267	380	417	266	96.5
St. Louis	0.744	58.7	102	190	267	382	417	267	96.5
Bart'ville	0.745	58.4	104	197	281	391	426	276	96.2
Denver	0.743	58.9	96	186	262	379	415	263	96.6
Laramie	0.749	57.4	99	193	266	376	409	265	96.7
San. Fran.	0.755	55.9	104	198	270	387	419	270	95.7
Average	0.748	57.7	102	193	267	381	417	267	96.4

A complete copy of Serial No. 2827, containing detailed tables of the analyses, can be obtained on request from the Bureau of Mines, Washington, D. C.

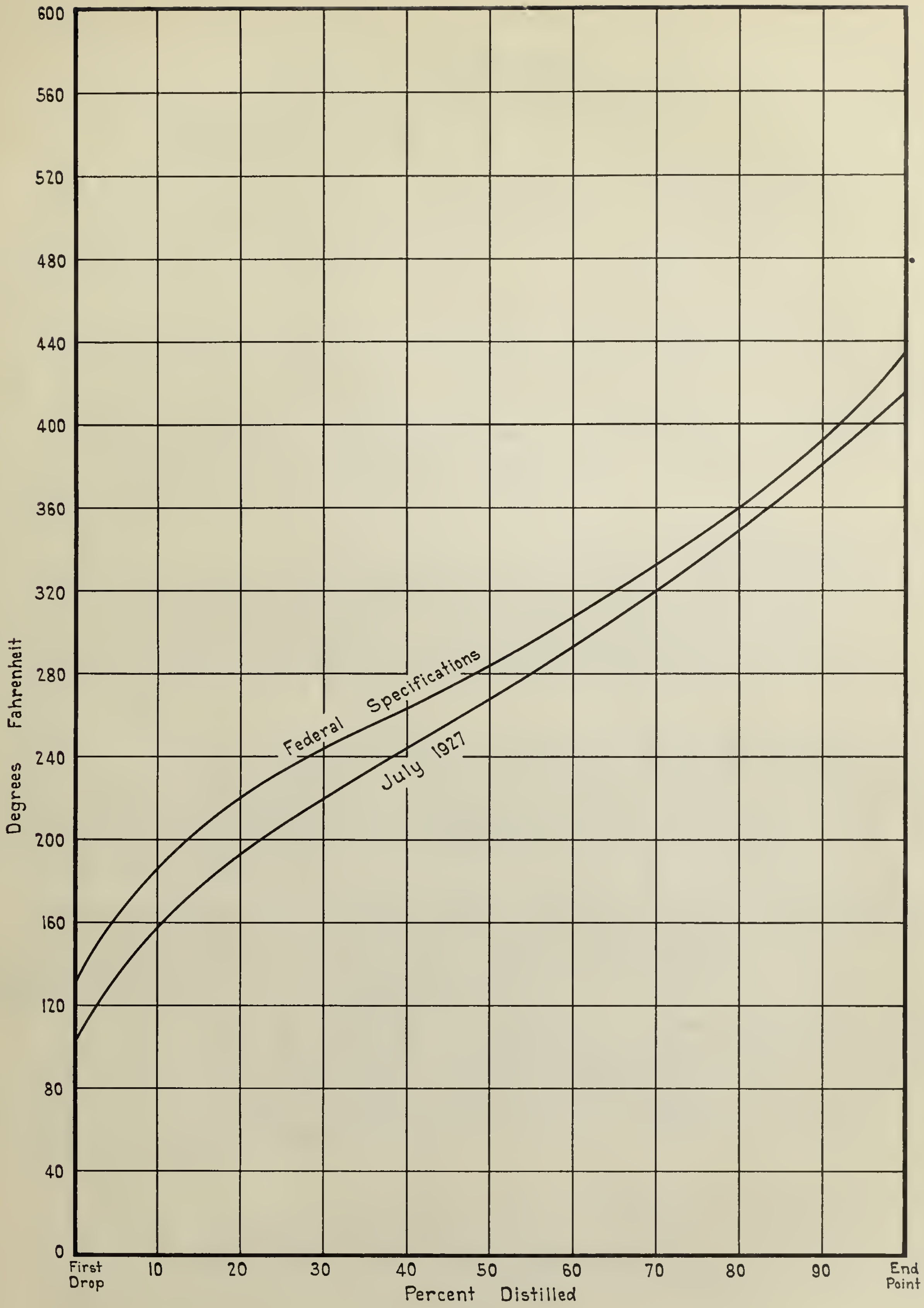


FIGURE 1

DISTILLATION CURVE OF AVERAGE GASOLINE

622.09
Un 32 mo
cop. 2

Serial No. 2829
September, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

PROGRESS OF FUEL ECONOMY AT PETROLEUM REFINERIES IN THE UNITED STATES

THE LIBRARY OF THE
JUL 23 1952
UNIVERSITY OF ILLINOIS

By G. R. Hopkins.

Like most industries, the refining industry has in recent years been confronted with the problem of a decreased margin of profit, due both to a general lowering of prices and to rising costs. This has resulted in accelerating a program of increased efficiency as evidenced by improved methods and the installation of equipment designed to effect a number of economies hitherto regarded as unimportant. Perhaps the most important of these has been that of fuel economy for, as is not often realized, a refinery consumes about one-tenth as much fuel as it produces.

A recently completed canvass, made by the Bureau of Mines for the purpose of determining the trend of fuel consumption at refineries in the United States, showed the following outstanding points, (1) a decrease in the use of oil for fuel in 1926 of approximately 4,000,000 barrels as compared with 1925; (2) a small decrease in the use of coal; (3) a material increase in the use of gas, both natural gas and refinery gas; and (4) a considerable increase in the use of petroleum coke.

The explanation of the decrease in the use of oil for fuel probably lies in the existence of a relatively strong fuel oil market in 1926. Wherever possible gas was substituted for oil. This was particularly evident in Texas where the consumption of oil decreased over 3,000,000 barrels, or 21 per cent, while the consumption of natural and refinery gas increased 63 per cent.

Every section of the country showed a gain in the use of refinery gas for fuel. In constructing systems whereby still gases are recovered, the refineries have effected a two-fold economy, namely, a saving of gasoline recovered from the gas and a saving of fuel through the burning of the residue gas.

As stated above, the quantity of coal used for fuel at refineries showed little change from 1925. Practically all of the coal is consumed in the eastern and central States, where natural gas is either lacking or prohibitive in price. The refineries of this area, therefore, were vitally interested in the matter of still-gas recovery, which they employed to obtain the fuel made necessary by increased operations.

Much attention has recently been given by refinery engineers to the problem of devising a thoroughly satisfactory burner to utilize the increasing production of pressure-still coke. That some progress was made in 1926 would seem to be indicated by the fact that the consumption at refineries increased from 314,000 short tons in 1925 to 408,000 short tons in 1926, the latter figure being equivalent to over 40 per cent of the total output.

As is quite well known, cracking has become one of the most important phases of modern refinery practice. This process, which consists, in brief, of breaking down high-boiling fractions into lower-boiling fractions by the application of heat, has by reason of the high temperature required, materially increased the fuel demands at refineries. Another factor which has tended to increase fuel consumption at refineries is the ever-growing practice of completely refining crude petroleum; that is, of recovering the lubricating, wax, and asphalt fractions instead of leaving them in the fuel oil.

In spite of added fuel requirements, the refineries have by more efficient and economical practice succeeded in reducing the consumption of fuel per barrel of crude petroleum refined. In order to arrive at this conclusion the consumption of the various fuels were reduced to their B. t. u. equivalents according to the following factors:

Oil	6,000,000	B. t. u.	per barrel
Coal.	26,000,000	do	per short ton
Gas	1,050	do	per cu. ft.
Coke.	30,000,000	do	per short ton
One kilowatt hour . . .	3,415	do	
Wood.	20,000,000	do	per cord

These factors gave a total of about 630,000,000,000,000 B. t. u. used in 1926 as compared with 600,000,000,000,000 B. t. u. in 1925 and 305,000,000,000,000 B. t. u. in 1919. There were 361,520,000; 739,920,000; and 779,264,000 barrels of crude petroleum refined in 1919; 1925; and 1926, respectively, which indicates a requirement of 849,000 B. t. u. per barrel in 1919, of 813,000 in 1925, and of 809,000 in 1926. This decline over a number of years is indicative of the success which has attended fuel economy.

The Appalachian area used the greatest number of B. t. u. per barrel of crude refined; and California, the least. In the case of the former, the explanation undoubtedly lies in the great number of small refineries, most of which completely refine the crude oil run to stills. Furthermore, many of these refineries use coal, which ranks comparatively low in the percentage of B. t. u. recovered and used. The fuel requirements of the California refineries per barrel increased in 1926 but are still relatively low, owing to the widespread use of the skimming and topping processes.

Fuel economy has resulted largely from a policy of efficient use rather than through the installation of new apparatus using less fuel. Thus hot still-gases are made to preheat the air for fuel combustion and also the feed-water for boilers. Heat exchangers, a system by which cold liquids are made to do part of the work of the condensers, have lowered both fuel and water requirements. Exhaust steam is receiving its share of attention, being used to heat buildings, agitators, etc. Operations at the modern refinery are usually conducted on a continuous basis, in contrast to the batch system. One of the most common features associated with modern refinery practice and continuous operation is the pipe-still, which is not only a time saver but a fuel economizer as well. - Reports of Investigations, Bureau of Mines, Department of Commerce.

Fuel used at refineries in the United States, 1925-1926.

	Oil 1/ (Thousands of bbls.	Coal (Thousands of short tons).	Gas (Million cu. ft.)		Coke (Thousands of short tons).	Other	Total B.t.u. (Billions approx).	Crude runs to stills (Thousands of bbls.)	B.t.u. per bbl. crude run
			Natural	Refinery					
1925									
East coast..........	14,164	1,406	- - -	6,863	104	(2/)	131,926	128,491	1,027,000
Appalachian..........	641	1,346	2,364	537	5	(3/)	42,038	25,118	1,674,000
Ind.,Ill.,etc........	2,997	3,077	- - -	5,505	33	(4/)	104,755	67,159	1,560,000
Oklahoma.............	2,552	1	25,670	3,295	- - -		45,751	61,837	740,000
Kansas and Missouri..	3,021	229	5,955	3,175	6		33,846	35,775	946,000
Texas Inland.........	2,277	- - -	4,900	422	8		19,490	35,957	542,000
Texas Gulf coast.....	13,189	- - -	12,956	7,354	79		102,830	108,325	949,000
Total Texas........	15,466	- - -	17,856	7,776	87		122,320	144,282	843,000
Ark.-La. Inland......	15	- - -	6,267	353	- - -		7,041	16,239	434,000
La. Gulf coast.......	4,920	- - -	- - -	2,518	59		33,934	50,758	668,000
Total La.-Ark......	4,935	- - -	6,267	2,871	59		40,975	66,997	612,000
Rocky Mountain.......	1,761	94	19,007	3,448	20		37,188	26,164	1,421,000
California...........	4,918	- - -	10,723	1,571	- - -		42,417	184,097	230,000
Total U. S......	50,455	6,153	87,842	35,041	314			739,920	813,000
Total B.t.u. (billions approx.)......	302,730	159,978	92,234	36,793	9,420	61	601,216	- - - -	- - - -
1926									
East coast...........	14,701	1,447	- - -	9,642	105		139,102	130,643	1,065,000
Appalachian..........	606	1,644	2,501	1,550	3	(5/)	50,724	28,502	1,780,000
Ind.,Ill.,etc........	3,130	2,677	1	7,649	35	(6/)	97,466	69,707	1,398,000
Oklahoma.............	2,010	6	25,957	5,425	7		45,377	61,409	739,000
Kansas and Missouri..	2,085	226	8,048	3,478	5		30,638	35,097	873,000
Texas Inland.........	1,954	- - -	3,626	537	10		16,395	36,183	453,000
Texas Gulf coast.....	10,325	- - -	25,121	12,370	127		105,126	119,927	877,000
Total Texas........	12,279	- - -	28,747	12,907	137		121,521	156,110	778,000
Ark.-La. Inland......	50	- - -	9,056	769	- - -		10,616	19,507	544,000
La. Gulf coast.......	4,808	- - -	- - -	3,803	101		35,871	51,505	696,000
Total La.-Ark......	4,858	- - -	9,056	4,572	101		46,487	71,012	655,000
Rocky Mountain.......	1,496	52	30,720	4,126	15		47,366	29,205	1,622,000
California...........	5,251	- - -	16,419	2,728	- - -		51,611	197,579	261,000
Total U. S......	46,416	6,052	121,449	52,077	408			779,264	809,000
Total B.t.u. (Billions approx.)......	278,495	157,352	127,522	54,681	12,240	1	630,292	- - - -	- - - -

1/ Includes acid sludge. 2/ 3,269 cords of wood. 3/ 72,632 kilowatts. 4/ 183,660 kilowatts. 5/ 102,901 kilowatts. 6/ 268,240 kilowatts.

Serial No. 2830
September, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - - BUREAU OF MINES

COAL-MINE FATALITIES IN AUGUST, 1927.

By W. W. Adams[1]

Accidents in the coal-mining industry in the United States in August, 1927, caused the death of 163 men, according to reports received from State mine inspectors by the United States Bureau of Mines, Department of Commerce. Included in this number were 137 deaths which occurred in bituminous mines; the other 26 deaths occurred in the anthracite field of Pennsylvania. The death rate per million tons of coal mined during the month was 3.30, based on a production of 49,454,000 tons, as compared with 4.67 for August, 1926, based on an output of 54,578,000 tons. The rate for bituminous coal alone for August, 1927, was 3.28 with a production of 41,705,000 tons, and that for anthracite was 3.36, with a tonnage of 7,749,000, as compared with 4.62 for bituminous and 4.98 for anthracite in August last year, based on a production of 46,352,000 tons and 8,226,000 tons, respectively.

Reports for the first eight months of 1927 show that accidents at coal mines caused the loss of 1,473 lives. The production of coal during this period was 405,649,000 tons. The death rate per million tons was therefore 3.63, representing a reduction of 9 per cent from the rate for the same eight months of 1926, when 1,641 deaths occurred and 410,237,000 tons of coal was produced. The record for bituminous mines alone from January to August of this year, was 1,146 fatalities and 351,971,000 tons, with a fatality rate of 3.26, while that for anthracite mines showed 327 deaths, 53,678,000 tons and a death rate of 6.09. The same eight-month period of 1926 showed 1,359 deaths and 357,330,000 tons with a rate per million tons of 3.80 for bituminous mines; and 282 deaths, 52,907,000 tons and a rate of 5.33 for anthracite mines.

On August 3 there was a major disaster - that is a disaster causing the loss of five or more lives - at Clay, Kentucky, which caused the death of 15 men. This accident was an explosion; it was the first major disaster since May and brings the number of such accidents for the first eight months of 1927 up to 8 with a resulting loss of 155 lives. There were 11 major disasters during the corresponding eight months of 1926 with a loss of 254 lives. The death rates per million tons of coal produced based exclusively on these major disasters were 0.38 and 0.62, respectively, for the 1927 and 1926 periods.

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

Comparing the accident record for the period January to August, 1927, with the same months of 1926, a reduction is noted in the death rates from falls of roof and coal, haulage, and gas or dust explosions, while a slight increase is shown for explosives and electricity. The comparative rates for the principal causes of accidents are as follows:

	Year 1926	Jan.-Aug. 1926	Jan.-Aug. 1927
All causes..............	3.790	4.000	3.631
Falls of roof and coal...	1.829	1.870	1.753
Haulage..................	.650	.700	.569
Gas or dust explosions:			
Local explosions......	.111	.127	.118
Major explosions......	.525	.619	.382
Explosives..............	.145	.139	.187
Electricity.............	.143	.156	.178

Tables 1 to 4 inclusive, present a detailed statistical comparison of the number and causes of accidents and corresponding rates in 1927 with similar figures for earlier years. Table 5 is a summary of figures relating to labor data for the coal industry as a whole from 1906 with averages for five-year periods. - - Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE 1 - NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES

(Includes both anthracite and bituminous coal)

	Year 1926	Jan.-Aug. 1926	Jan.-Aug. 1927
Falls of Roof & Coal	1.829	1.870	1.753
At face	1.386	1.468	1.304
In room	.238	.217	.230
On entry	.193	.180	.212
On slope	.012	.005	.007
Haulage	.650	.700	.569
Switching and spragging	.020	.020	.005
Coupling	.008	.010	.022
Falling from trips	.030	.022	.034
Run over	.241	.258	.232
Caught between car and rib	.136	.151	.143
Caught between car and roof	.027	.027	.032
Runaway cars	.057	.049	.057
Miscellaneous	.131	.163	.044
Gas or Dust Explosions	.636	.746	.500
Open light	.191	.093	.081
Defective safety lamp	.005	.007	.003
Electric arc	.081	.120	.059
Shot	.077	.117	.029
Powder explosion	.005	.007	.003
Miscellaneous	.277	.402	.325
Explosives	.145	.139	.187
Transportation	-----	-----	.003
Charging	.006	.010	.005
Suffocation	.008	.005	----
Drilling into old holes	.003	.003	----
Striking in loose rocks	-----	-----	----
Thawing	-----	-----	----
Caps & detonators	.001	.003	.007
Unguarded shots	.006	.005	.007
Returned too soon	.013	.017	.012
Premature shot	.048	.034	.067
Sparks from lamp, etc	.005	.007	.007
Delayed shots	.015	.014	.015
Shot breaking through rib	.011	.012	.022
Miscellaneous	.029	.029	.042
Electricity	.143	.156	.178
Direct contact with trolley wire	.050	.043	.067
Tools striking trolley wire	.003	.005	.003
Contact with mining machine	.013	.005	.022
Contact with machine feed wire	.009	.010	.027
Contact with haulage motor	.003	-----	----
Miscellaneous	.065	.093	.059

TABLE 2 - COAL-MINE FATALITIES DURING AUGUST, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																													
Falls of roof..........	9	-	-	3	1	-	-	-	10	-	-	-	-	1	-	2	-	16	-	2	-	1	3	-	25	4	77	11	88
Falls of side..........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3	1	4
Haulage................	-	-	1	-	-	-	-	-	2	-	-	-	-	1	-	1	-	4	-	1	-	-	1	-	6	1	18	3	21
Gas or dust explosions...	-	-	-	-	-	1	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	2	18
Explosives.............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	3	4
Suffocated by mines gases	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electricity............	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	2	-	8	1	9
Animals................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	1
Mining machines........	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	4	-	4
Mine fires.............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other cases............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3	1	4
TOTAL..........	9	-	1	4	1	1	2	-	29	-	-	-	-	2	-	3	-	30	-	3	-	1	5	1	34	5	131	22	153
SHAFT																													
Persons falling........	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3
Objects falling........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cages, skips...........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes...........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL..........	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3
SURFACE																													
Mine cars..............	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Electricity............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1	2
Machinery..............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boiler explosions......	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Railway cars...........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Other causes...........	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	1	3
TOTAL..........	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-	4	3	7
GRAND TOTAL, August, 1927	9	0	1	4	2	1	2	1	30	0	0	0	1	2	0	3	0	31	0	3	0	1	5	1	35	5	137	26	163
GRAND TOTAL, August, 1926	10	0	1	5	14	3	1	0	17	1	0	0	0	2	1	6	2	71	0	2	0	3	4	1	68	2	214	41	255

TABLE 3 - COAL-MINE FATALITIES DURING 1927 and 1926, BY MONTHS AND STATES.

MONTH	Ala	Alas	Ark	Col	Ga. & N.C.	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January................	6	–	2	8	–	19	3	1	–	23	–	1	1	1	2	–	7	2	35	–	3	–	1	2	1	43	4	165	45	210
February..............	7	–	2	5	–	11	6	1	2	10	–	–	–	1	2	2	9	2	31	–	–	–	5	5	2	35	–	138	41	179
March.................	6	–	–	7	–	23	7	1	2	6	–	–	–	–	2	–	6	2	35	–	3	–	2	3	1	38	1	145	41	186
April..................	6	–	–	2	–	4	–	2	–	2	–	1	–	1	–	–	3	2	33	–	1	–	3	3	7	144	–	214	40	254
May....................	6	–	1	8	–	4	–	1	–	11	–	–	–	–	1	–	5	1	25	–	–	–	3	9	2	50	1	128	53	181
June...................	4	–	1	3	–	–	2	–	1	5	1	–	–	2	3	–	3	2	29	–	–	–	2	1	1	53	1	114	52	166
July...................	11	–	1	1	–	–	1	–	1	17	1	–	–	–	–	–	5	3	24	–	3	–	1	–	1	34	1	105	29	134
August.................	9	–	1	4	–	2	1	2	1	30	–	–	–	1	2	–	3	–	31	–	3	–	1	5	1	35	5	137	26	163
TOTAL, 8 months, 1927	55	0	8	38	0	63	20	8	7	104	2	2	1	6	12	2	41	14	243	0	13	0	18	28	16	432	13	1,146	327	1,473
TOTAL, 8 months, 1926	103	1	3	35	1	95	23	5	11	123	7	1	2	2	11	1	51	103	284	0	17	0	13	33	6	410	18	1,359	282	1,641
TOTAL, 1926......	139	1	7	53	3	166	78	16	17	178	12	1	9	5	13	1	80	124	420	0	50	0	20	58	15	573	22	2,061	453	2,514

TABLE 4 - AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED

Cause of accident	Per cent of total 1917-1926	Death rates per million short tons						
		Average for 10 years 1917-1926	Year 1925	Year 1926	Average for August 10 years 1917-1926	1927		1926
						July	Aug.	Aug.
		Bituminous Mines						
1. Falls of roof and coal	48.96	1.759	1.750	1.717	1.843	1.635	1.918	1.941
2. Underground haulage.	18.18	.653	.586	.655	.691	.683	.431	.755
3. Explosions of gas or coal dust:								
Local explosions	2.91	.104	.112	.080	.078	.060	.024	.065
Major explosions	10.84	.390	.469	.565	.622	- - -	.360	.949
4. Explosives	3.30	.118	.094	.080	.108	.119	.024	.043
5. Electricity.	4.01	.144	.154	.161	.175	.416	.192	.324
6. Mining machines.	1.33	.048	.067	.045	.057	.060	.096	.065
7. Other causes underground . . .	2.93	.105	.089	.067	.106	- - -	.096	.108
8. All causes underground	92.46	3.321	3.321	3.370	3.680	2.973	3.141	4.250
9. All shaft accidents.	1.73	.062	.058	.047	.080	.060	.048	.043
10. All accidents on surface . . .	5.81	.209	.148	.147	.250	.089	.096	.324
11. All accidents.	100.00	3.592	3.527	3.564	4.010	3.122	3.285	4.617
		Anthracite Mines						
1. Falls of roof and coal	42.71	2.496	2.750	2.588	2.241	2.585	1.549	2.674
2. Underground haulage.	12.75	.745	.906	.612	.720	.796	.387	.608
3. Explosions of gas:								
Local explosions	6.71	.392	.421	.329	.414	.398	.258	.486
Major explosions	1.51	.088	.275	.247	.133	- - -	- - -	- - -
4. Explosives	12.37	.723	.857	.588	.654	.796	.387	.729
5. Electricity.	1.00	.059	.065	.024	.120	.198	.129	.122
6. Other causes underground . . .	8.18	.478	.323	.459	.494	.398	.129	.122
7. All causes underground	85.23	4.981	5.597	4.847	4.776	5.171	2.839	4.741
8. All shaft accidents.	2.30	.134	.065	.094	.027	.597	.129	- - -
9. All accidents on surface . . .	12.47	.729	.809	.388	.640	- - -	.387	.243
10. All accidents.	100.00	5.844	6.471	5.329	5.443	5.768	3.355	4.984

Table 5 - Fatality rates for all coal mines in the United States for the years 1906 to 1926.

Year	Men employed		Average days active	Total shifts	Men killed	Killed per thousand 300-day workers	Production (short tons)	Production per death (short tons)	Average production per man		Deaths per million tons
	Actual number	Equivalent in 300-day workers							Tons per year	Tons per day	
1906 1/	630,283	439,097	209	131,729,147	2,138	4.87	405,955,888	189,876	644	3.08	5.27
1907 1/	674,613	519,452	231	155,835,603	3,242	6.24	477,892,536	147,407	708	3.07	6.78
1908 1/	678,873	441,267	195	132,380,235	2,445	5.54	409,309,857	167,407	603	3.09	5.97
1909 1/	665,535	490,763	221	147,228,770	2,642	5.38	460,807,263	174,416	691	3.13	5.73
1910	725,030	531,689	220	159,506,600	2,821	5.31	501,596,378	177,808	692	3.14	5.62
Average	675,067	484,454	215	145,336,071	2,658	5.49	451,112,384	169,719	668	3.10	5.89
1911	728,348	534,122	220	160,236,560	2,656	4.97	496,371,126	186,887	682	3.10	5.35
1912	722,662	541,997	225	162,598,950	2,419	4.46	534,466,580	220,945	740	3.29	4.53
1913	747,644	593,131	238	177,939,272	2,785	4.70	570,048,125	204,685	762	3.20	4.89
1914	763,185	526,598	207	157,979,295	2,454	4.66	513,525,477	209,261	673	3.25	4.78
1915	734,008	511,598	209	153,479.495	2,269	4.44	531,619,487	234,297	724	3.46	4.27
Average	739,169	541,489	220	162,446,714	2,517	4.65	529,206,159	210,253	716	3.26	4.76
1916	720,971	565,766	235	169,729,816	2,226	3.93	590,098,175	265,094	818	3.48	3.77
1917	757,317	634,666	251	190,399,680	2,696	4.25	651,402,374	241,618	860	3.42	4.14
1918	762,426	654,973	258	196,491,984	2,580	3.94	678,211,904	262,873	890	3.45	3.80
1919	776,569	542,217	209	162,665,023	2,323	4.28	553,952,259	238,464	713	3.41	4.19
1920	784,621	601,283	230	180,384,942	2,272	3.78	658,264,932	289,729	839	3.65	3.45
Average	760,381	599,781	237	179,934,289	2,419	4.03	626,385,929	258,944	824	3.48	3.86
1921	823,253	474,529	173	142,358,691	1,995	4.20	506,395,401	253,832	615	3.56	3.94
1922	844,807	405,056	144	121,516,822	1,984	4.90	476,951,121	240,399	565	3.92	4.16
1923	862,536	560,646	195	168,193,738	2,462	4.39	657,903,671	267,223	763	3.91	3.74
1924	779,613	499,896	192	149,968,980	2,402	4.80	571,613,400	237,974	733	3.81	4.20
1925	748,805	480,227	192	144,068,232	2,234	4.65	581,869,890	260,461	777	4.04	3.84
Average	811,803	484,071	179	145,221,293	2,215	4.58	558,946,697	252,346	689	3.85	3.96
1926	2/742,000	--------	----	------------	2,514	----	3/663,290,000	263,943	894	----	3.79

1/ Figures are only for States under inspection service. Figures for 1909 as to average days active and total shifts were estimated by the Bureau of Mines.

2/ Number of employees based on estimates of State mine inspectors.

3/ Estimated.

Serial No. 2831.
September, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

CONSUMPTION OF EXPLOSIVES IN AUGUST, 1927.

By W. W. Adams[1]

The amount of explosives manufactured in the United States and sold in August 1927 for domestic consumption was 446,900 kegs of 25 pounds each (11,172,500 pounds) of black blasting powder, 5,151,000 pounds of permissible explosives, and 27,918,000 pounds of other high explosives. These figures are based on reports from manufacturing companies to the Bureau of Mines, Department of Commerce, and include an estimate of sales by several companies that do not furnish monthly reports. Reports actually received from manufacturers show sales of 437,991 kegs (10,949,775 pounds) of black blasting powder, 5,143,499 pounds of permissibles, and 26,231,620 pounds of other high explosives. Compared with August 1926, the sales in August 1927 represent a decrease of 7 per cent in black powder, 15 per cent in permissibles, and 5 per cent in other high explosives.

PERMISSIBLE EXPLOSIVES: Sales of permissible explosives during the first eight months of 1927 amounted to 41,745,000 pounds, including 41,682,888 pounds actually reported and an estimate of sales by several non-reporting companies. The present year's sales represent an increase of 2 per cent over the corresponding eight months of 1926. About 96 per cent of the permissibles sold thus far in 1927 have been for use in coal-mining operations (67 per cent for bituminous coal mining and 29 per cent for anthracite mining). The remainder was used for other mining, quarrying, construction work, and various other purposes. In the bituminous coal-mining industry the amount of all classes of explosives used during the first eight months of 1927 has averaged 267 pounds for each thousand tons of coal produced; of this average quantity, 79 pounds (30 per cent) were explosives of permissible types. Corresponding records for anthracite mines show an eight-month average consumption of 742 pounds of all kinds of explosives per thousand tons of coal, of which quantity 227 pounds (31 per cent) were permissible. The largest coal-producing States continued, as in previous months, to use more permissibles than any other States as shown by the following: Pennsylvania 20,959,290 pounds, West Virginia 9,255,900 pounds, Alabama, 3,339,200 pounds, Kentucky 2,310,625 pounds, and Illinois 1,046,075 pounds. Sales to these States represent 89 per cent of the total quantity of permissibles reported sold in the eight-month period in the entire United States.

BLACK BLASTING POWDER: The quantity of black blasting powder sold during the first eight months of 1927 was 3,335,200 kegs, including 3,268,550 kegs sold by reporting companies and an estimate of sales by non-reporting companies. These figures represent a decrease of 12 per cent in volume of sales as compared with the corresponding months last year. Of the total amount sold, 84 per cent was used for coal-mining operations (11 per cent in anthracite mines and 73 per cent in bituminous mines) while 16 per cent was used for metal mining, quarrying, construction work, and all other purposes. Of 267 pounds of all types of explosives used at bituminous coal mines since the first of the year for each thousand tons of coal produced, 172 pounds (64 per cent) were black blasting powder. At the anthracite mines where 742 pounds of all classes of explosives were used per thousand tons of coal, 178 pounds (24 per cent) were black blasting powder. The following seven States have used the largest quantities of black blasting powder since the beginning of the year: Pennsylvania 654,751 kegs, Kentucky 461,569 kegs, West Virginia 352,147 kegs, Illinois 345,193 kegs, Indiana 300,746 kegs, Ohio 163,187 kegs, and Kansas 113,256 kegs. The total amount used by these States represents 73 per cent of all reported sales of black blasting powder during the first eight months of the present year.

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

OTHER HIGH EXPLOSIVES: The August sales of high explosives other than permissibles brought the total sales of this class of explosives during the first eight months of 1927 to 206,080,000 pounds, a decrease of a little over a million pounds of the quantity sold during the same period in 1926. The sales for 1927 include 193,633,206 pounds actually reported to the Bureau of Mines and an estimate of sales by several companies that do not furnish monthly reports. Metal mining, quarrying and nonmetallic mineral mining used the greatest amount of this class of explosives, during the period January to August, 59 per cent of the total quantity of "high" explosives being so used. Coal mines used 11.5 per cent (8.8 per cent for anthracite mines and 2.7 per cent for bituminous mines); railway and other construction work 16.4 per cent; and miscellaneous purposes 13.2 per cent. Consumption of all classes of explosives at bituminous coal mines during the first eight months of 1927 has averaged 267 pounds per thousand tons of coal produced; of this quantity 16 pounds (6 per cent) were high explosives other than permissibles. At anthracite mines, the average consumption has been 742 pounds of all kinds of explosives per thousand tons of coal, of which 337 pounds (45 per cent) were high explosives other than permissibles. The largest quantities of this class of explosives sold since the beginning of this year were in the States of Pennsylvania, Michigan, California, New York, Minnesota, Ohio, Oklahoma, Florida, Missouri, Texas, Alabama, Washington, Utah, Illinois, and Kansas. The combined sales to these States represent 71 per cent of the total sales reported for this class of explosives.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in August were more than 352,200 kegs, showed that the mills were operated to 45 per cent of their capacity in August as compared with 37 per cent in July, 40 per cent in June, and 39 per cent in August last year. The amount of explosives remaining on hand at the close of August represented 52 per cent of one month's manufacturing capacity of the mills reporting, as compared with 46 per cent at the close of August a year ago.

	August, 1926	August, 1927	Jan.-Aug., 1927
Capacity (Kegs)..........	953,583	796,083	6,368,664
Manufactured.............	368,303	355,568	2,593,729
Per cent of capacity......	39	45	41
Shipments................	359,013	354,873	2,580,746
Per cent of capacity......	38	45	41
Sales....................	345,368	352,231	2,510,688
Per cent of capacity......	36	44	39
Stocks, end of month......	439,726	417,814	417,814
Per cent of capacity......	46	52	6.6

The following percentage figures show the extent of capacity to which mills manufacturing black powder were operated in 1924, 1925, 1926, average for eight months in 1926 and in the months of January to August, 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month.

	Manufactured	Shipments	Sales	Stocks
Year 1924...........	41	41	41	3.8
Year 1925...........	38	39	38	3.2
Year 1926...........	40	40	39	3.6
Average, 8 mos. 1926.	37	36	36	5.8
1927				
January..............	54	55	56	50
February.............	54	47	45	58
March................	36	36	38	58
April................	31	32	30	57
May..................	29	36	35	49
June.................	40	37	33	52
July.................	37	36	34	53
August...............	45	45	44	52
Average, 8 months....	41	41	39	6.6

Reports from 23 mills that sold more than 25 million pounds of permissibles and other high explosives in August showed that the mills were operated to 67 per cent of their capacity in August as compared with 58 per cent in July, 65 per cent in June, and 74 per cent in August last year. The amount of explosives remaining on hand at the close of August represented 17 per cent of one month's manufacturing capacity of the mills reporting, as compared with 15 per cent at the close of August a year ago.

	August, 1926	August, 1927	Jan.-Aug., 1927
Capacity (Pounds)..........	39,153,332	40,945,000	316,810,000
Manufactured...............	28,815,037	27,414,654	204,084,683
Per cent of capacity.......	74	67	64
Shipments..................	28,198,177	26,864,424	203,817,178
Per cent of capacity.......	72	66	64
Sales......................	28,387,198	25,274,642	196,213,594
Per cent of capacity.......	73	63	62
Stocks, end of month.......	5,900,665	6,898,592	6,898,592
Per cent of capacity.......	15	17	2.1

The percentage of full-time capacity to which mills manufacturing permissibles and other explosives were operated in 1924, 1925, 1926, average for eight months in 1926, and in the months of January to August 1927, is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining on hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924..............	62	62	59	1.4
Year 1925..............	62	62	59	1.5
Year 1926..............	68	68	64	1.4
Average, 8 mos. 1926....	66	67	64	1.8
1927				
January................	59	58	57	19
February...............	63	62	57	20
March..................	64	64	62	20
April..................	66	69	65	17
May....................	73	72	69	18
June...................	65	66	64	17
July...................	58	58	58	15
August.................	67	66	63	17
Average, 8 months.......	64	64	62	2.1

PYROTOL: During the first eight months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 10,427,960 pounds of pyrotol of which 780,150 pounds represented shipments in August. During the corresponding eight months last year the shipments amounted to 10,843,650 pounds. Most of the pyrotol shipped was for use by farmers in clearing land. Table D shows the amount of pyrotol shipped to each State in August 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal-mining operations in each State from January to August 1927 is shown in Table C. Table D shows the quantity of pyrotol distributed in August to the various States.--Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE A - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during August, 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	11,014	696,950	414,950
Alaska	-	152,600	-
Arizona	2,390	122,325	-
Arkansas	6,754	193,242	15,700
California	10,831	1,315,185	-
Colorado	4,843	452,050	75,800
Connecticut	102	153,600	-
Delaware	2	6,329	-
Florida	3,960	825,550	-
Georgia	1,385	119,675	-
Idaho	1,456	292,000	-
Illinois	25,141	919,737	26,100
Indiana	44,017	489,760	64,450
Iowa	4,554	231,850	1,000
Kansas	11,902	670,633	8,750
Kentucky	73,380	568,850	387,500
Louisiana	-	344,527	24,550
Maine	341	61,275	-
Maryland & D.C.	2,566	199,100	2,650
Massachusetts	85	103,850	-
Michigan	1,000	1,864,575	50
Minnesota	5,232	1,413,875	-
Mississippi	80	136,300	-
Missouri	10,587	850,710	1,200
Montana	7,981	484,525	4,100
Nebraska	53	16,300	-
Nevada	800	282,900	-
New Hampshire	31	21,200	-
New Jersey	4	381,975	-
New Mexico	29	9,750	-
New York	1,426	1,594,825	-
N. Carolina	2,734	320,375	2,000
N. Dakota	905	25,975	-
Ohio	17,393	994,525	28,800
Oklahoma	9,838	1,006,005	12,054
Oregon	4,296	364,650	250
Pennsylvania	91,998	3,980,384	2,709,175
Rhode Island	15	23,400	-
S. Carolina	603	73,025	-
S. Dakota	47	146,745	-
Tennessee	10,528	343,445	33,850
Texas	4,624	922,715	24,000
Utah	2,720	737,850	94,245
Vermont	51	23,950	-
Virginia	5,417	356,000	95,300
Washington	3,023	794,178	40,550
West Virginia	46,345	514,625	1,008,575
Wisconsin	239	502,550	-
Wyoming	5,269	125,200	67,900
TOTAL AUGUST 1927	437,991	26,231,620	5,143,499

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first eight months of 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	74,151	5,765,569	3,339,200
Alaska	321	1,472,690	58,700
Arizona	14,965	1,130,300	-
Arkansas	38,290	1,043,191	89,733
California	54,966	12,046,788	-
Colorado	34,477	3,553,566	548,700
Connecticut	346	1,051,700	-
Delaware	2	56,399	-
Florida	18,214	6,882,972	-
Georgia	11,107	1,294,175	-
Idaho	4,131	2,706,568	8,850
Illinois	345,193	5,302,902	1,046,075
Indiana	300,746	2,653,185	348,850
Iowa	63,981	1,805,675	4,450
Kansas	113,256	5,002,959	170,515
Kentucky	461,569	3,295,805	2,310,625
Louisiana	350	1,732,511	73,300
Maine	1,463	465,850	-
Maryland & D.C.	18,070	1,581,800	105,500
Massachusetts	1,121	817,625	-
Michigan	6,418	14,077,350	1,200
Minnesota	27,930	8,727,552	-
Mississippi	2,061	900,550	-
Missouri	51,018	6,548,607	101,631
Montana	36,424	4,317,642	17,950
Nebraska	1,480	127,800	-
Nevada	24,256	2,272,025	200
New Hampshire	324	118,300	-
New Jersey	61	2,291,725	-
New Mexico	11,726	390,525	208,300
New York	8,875	10,221,524	30,400
N. Carolina	20,593	2,568,875	7,750
N. Dakota	10,157	88,357	9,975
Ohio	163,187	7,576,195	136,200
Oklahoma	73,375	7,415,907	159,334
Oregon	17,186	2,782,625	250
Pennsylvania	654,751	31,042,749	20,959,290
Rhode Island	105	68,800	-
S. Carolina	2,367	539,075	-
S. Dakota	417	836,565	1,300
Tennessee	77,457	2,629,045	233,350
Texas	56,749	6,266,155	38,850
Utah	12,626	5,484,215	572,645
Vermont	2,161	293,600	-
Virginia	44,143	2,613,125	886,590
Washington	29,856	5,627,788	412,125
West Virginia	352,147	3,649,400	9,255,900
Wisconsin	3,566	3,560,700	50
Wyoming	20,415	934,200	545,100
TOTAL 1st 8 MOS. 1927	3,268,550	193,633,206	41,682,888

AUGUST, 1927

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs	Pounds	Pounds
Quantity used for:			
Coal mining....................	362,940	3,011,358	4,919,958
Metal mining..................	7,296	7,415,005	30,850
Quarrying and nonmetallic mineral mining..............	20,053	7,373,130	44,300
Railway and other construction work........................	25,586	4,962,874	5,425
All other purposes............	32,116	3,469,253	142,966
TOTAL AUGUST 1927...............	437,991	26,231,620	5,143,499

JANUARY TO AUGUST, 1927, INCLUSIVE.

	Black blasting powder	High explosives other than permissible	Permissible explosives
Quantity used for:			
Coal mining....................	2,746,645	22,241,409	39,933,064
Metal mining..................	61,969	59,109,852	77,975
Quarrying and nonmetallic mineral mining..............	160,394	54,973,058	345,370
Railway and other construction work........................	170,422	31,656,637	150,611
All other purposes............	129,120	25,652,250	1,175,868
TOTAL 1st 8 MOS. 1927..........	3,268,550	193,633,206	41,682,883

TABLE C - Quantity of explosives sold for use in COAL MINES in August 1927 by manufacturers rendering monthly reports.

(Including cumulative figures for the first eight months of 1927)

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama........	9,003	57,228	58,150	406,644	413,900	3,316,200
Arkansas.......	6,561	37,612	4,100	41,700	3,000	11,683
Colorado.......	3,125	24,556	9,600	123,325	73,350	507,250
Illinois.......	24,170	340,179	69,400	266,650	22,000	959,450
Indiana........	43,129	295,286	156,125	549,175	61,525	317,225
Iowa...........	4,450	61,042	7,175	71,500	1,000	3,000
Kansas.........	10,757	107,585	51,100	421,076	8,500	168,715
Kentucky.......	71,193	439,455	112,650	673,400	374,900	2,113,405
Maryland.......	2,400	14,426	5,500	33,100	2,650	57,350
Michigan.......	1,000	4,917	6,150	33,300	-	-
Missouri.......	7,944	36,683	13,700	101,150	1,100	28,231
Montana........	6,133	25,996	4,300	10,550	1,100	7,950
New Mexico.....	-	2,805	2,000	19,600	-	196,050
North Dakota...	900	9,866	21,550	55,875	-	9,975
Ohio...........	14,034	138,341	18,925	283,500	12,150	55,150
Oklahoma.......	9,136	65,223	24,850	93,500	7,788	130,875
Penna. (Bitum.)	30,771	233,178	98,558	906,183	1,045,300	8,443,495
Tennessee......	8,942	65,776	19,800	111,250	23,400	215,500
Texas..........	1,830	15,153	-	5,700	-	-
Utah...........	-	-	550	34,250	91,745	561,645
Virginia.......	4,079	35,729	25,300	161,800	94,800	875,690
Washington.....	663	9,761	3,000	58,650	23,500	284,650
West Virginia..	45,014	334,370	106,800	668,250	976,325	8,963,850
Wyoming........	2,764	10,345	2,000	37,650	67,450	463,150
Other States...	1,015	6,030	3,500Rtd.	77,975	2,250	74,850
Total (Bitum.).	309,013	2,371,542	817,783	5,255,753	3,307,733	27,765,339
Penna. (Anth.).	53,927	375,103	2,193,575	16,985,656	1,612,225	12,167,725
Grand total as reported....	362,940	2,746,645	3,011,358	22,241,409	4,919,958	39,933,064
Est. total inc. non-reporting companies	) Anth.	382,900		18,073,000		12,185,000
	) Bitum.	2,420,000		5,585,000		27,806,000
Total reported plus estimate..		2,802,900		23,658,000		39,991,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period August 1, 1927 to August 31, 1927.

State	State Highway Department Roads	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
Alabama.............	2,000	-	-	-	2,000
Arizona.............	-	-	44,000	-	44,000
Arkansas............	60,000	-	-	-	60,000
California..........	-	-	20,000	24,000	44,000
Colorado............	-	-	25,000	-	25,000
Georgia.............	-	-	5,000	-	5,000
Idaho...............	-	-	10,000	-	10,000
Michigan............	-	36,000	-	-	36,000
Minnesota...........	500	-	-	-	500
Montana.............	-	-	44,000	-	44,000
Nevada..............	-	-	20,000	-	20,000
Oregon..............	66,000	32,150	78,400	-	176,550
S. Dakota...........	-	-	12,000	-	12,000
Utah................	-	-	12,000	-	12,000
Washington..........	71,000	69,400	36,000	-	176,400
Wisconsin...........	-	82,700	-	-	82,700
Wyoming.............	-	-	30,000	-	30,000
Total August........	199,500	220,250	336,400	24,000	780,150
Total July..........	140,850	444,000	122,000	20,000	726,850
Total June..........	225,300	685,250	108,300	72,900	1,091,750
Total May...........	162,000	825,500	26,000	352,100	1,365,600
Total April.........	281,550	1,669,550	7,500	222,000	2,180,600
Total March.........	249,500	1,916,860	-	108,700	2,275,060
Total February......	170,750	1,020,150	-	-	1,190,900
Total January.......	93,000	704,050	-	20,000	817,050
Grand Total.........	1,522,450	7,485,610	600,200	819,700	10,427,960

622.09
Un32mo
cop.2

erial No. 2834.
October, 1927.

REPORT OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

REDUCTION OF BREATHING LOSSES FROM VAPOR-TIGHT LEASE TANKS

By Ludwig Schmidt [1]

(In Cooperation with the State of Oklahoma)

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

Introduction

The use of vapor-tight tanks has proved so effective in reducing the evaporation losses of petroleum that today practically all operators are using this type of equipment. It has been shown, however, that vapor-tight tanks should be supplemented with additional measures which will further reduce evaporation. Probably the most effective use of the supplemental measures are found on the small producing leases where the breathing losses from vapor-tight stock tanks materially affect the volume and gravity of the stored oil. The breathing loss from a vapor-tight stock tank that is filled and emptied daily is a negligible quantity. Also, the filling loss, which on the average varies between 0.1 and 0.2 per cent, usually is not of a sufficient quantity to affect materially the value of the crude. However, the combined breathing and filling losses from a vapor-tight tank requiring several days to fill are of sufficient importance to warrant the use of measures in addition to the vapor-tight tanks. The breathing losses are caused by atmospheric variations. Probably the greatest are the changes in atmospheric temperature which cause changes in temperature of the vapors in the tank. During the day, as the temperature increases, the gasoline-saturated vapors in the tank expand and are forced out into the atmosphere. At night the vapors are cooled and contract, drawing into the tank fresh air, which becomes saturated with gasoline vapor and is forced out of the tank during the following day. In addition to the maximum and minimum temperature variations there are many smaller variations throughout a twenty-four-hour period caused by showers, clouds, winds, and other atmospheric conditions which likewise cause the tank to breathe.

The two most common measures used by lease operators for reducing breathing losses in vapor-tight tanks are, first, operating lease tanks under pressure, and second, the use of light colored paints and tank houses. In this report these two methods are discussed together with their adaptability to lease operation. Results of experimental observations are given which show the reduction of evaporation losses where these supplemental measures have been used.

---

[1] Associate petroleum engineer, Bureau of Mines, Department of Commerce.

Maintaining of Pressure on Tanks

The operation of lease tanks under pressure prevents gasoline-laden vapor from leaving the tank until certain definite and predetermined pressures are built up within the tank. This restricts the movement of vapors due to temperature variations and reduces the movements due to other atmospheric changes such as windage and barometric pressure.

The holding of pressure on lease tanks is not limited from considerations of construction, for there are now on the market bolted tanks operating under working pressures up to eighteen or twenty ounces, and many producers are using riveted or welded tanks, operating under pressures as high as five pounds. Local conditions of lease operation, however, may limit the amount of pressure held on stock and flow tanks.

It must be kept in mind that to eliminate all breathing by the use of pressure relief valves, the valves must be set to operate at a slightly higher pressure than the maximum developed within the tank. This internal pressure is the vapor pressure of the oil plus the pressure due to the expansion of the air-vapor mixture caused by atmospheric changes.

Tests on Pressure Tanks

In order to determine the actual value of holding pressure on lease stock tanks, a comparative test was made between two 65-barrel tanks; one was equipped with a pressure and vacuum release valve operating at about one and one-half ounces pressure or vacuum; the other was equipped with a valve operating at 16 ounces pressure and 2 ounces vacuum. The valves were of the dead weight type.

In order to duplicate filling conditions on a small lease the test tanks were partly filled at regular intervals with oil having an average gravity of 37.5° A.P.I. Gages, temperatures of the oil, and samples were taken at the beginning and end of each filling period. From these data the evaporation loss for each interval was obtained, also the total evaporation loss for the entire filling period. The oil passed through a combination flow tank and gas separator before entering the stock tanks.

Results of Tests on Pressure Tanks

Observations were made over a period of thirty-six days during the months of January and February. The average atmospheric temperature was 46°F. The total volumetric loss for the tank equipped with the 2-ounce pressure relief valve was 1.40 per cent, with a gravity loss of 0.55° A.P.I. The total volumetric loss for the tank equipped with the 16-ounce pressure relief valve was 0.59 per cent, with a gravity loss of 0.3° A.P.I.

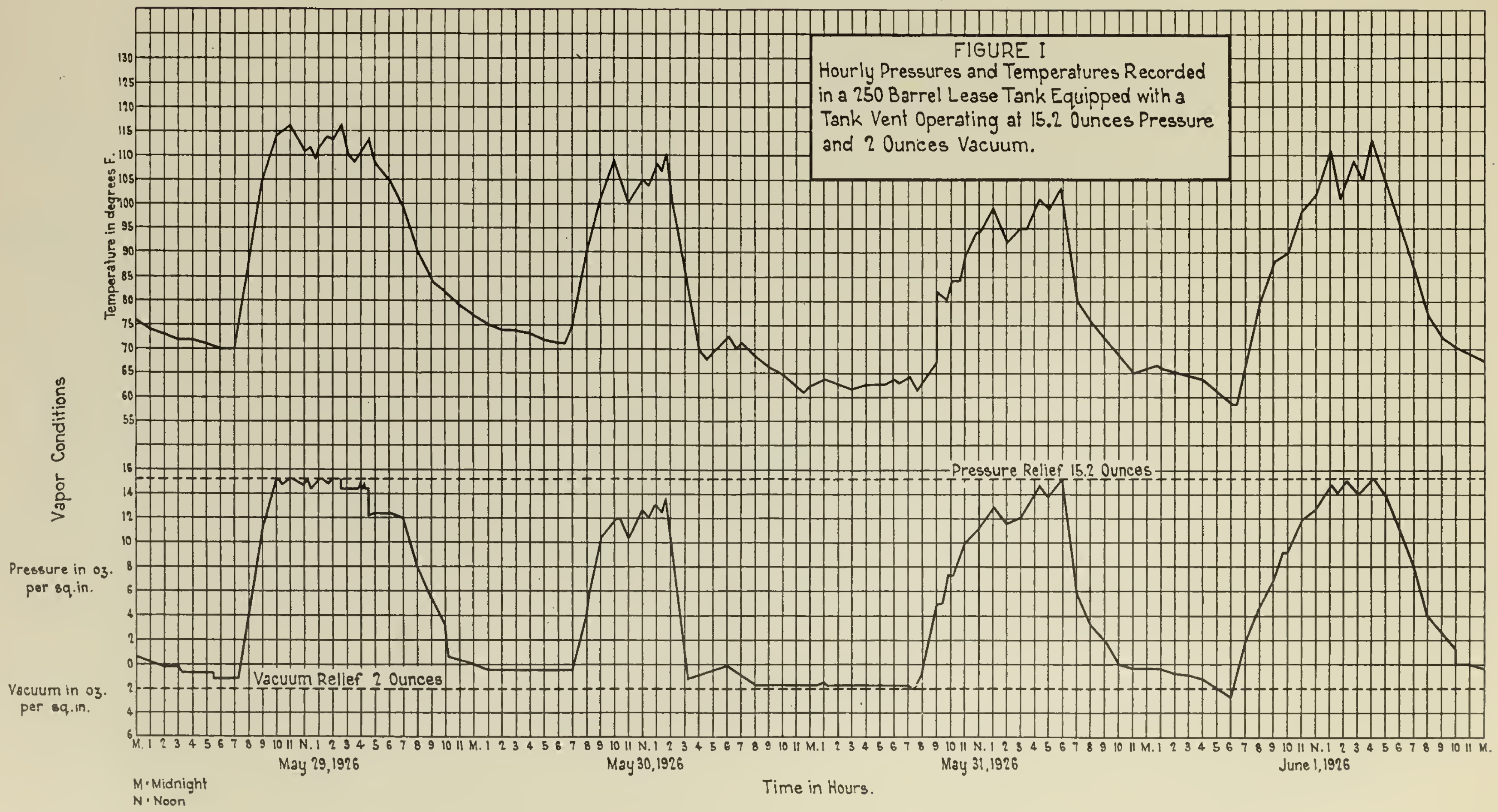


FIGURE I

Hourly Pressures and Temperatures Recorded in a 250 Barrel Lease Tank Equipped with a Tank Vent Operating at 15.2 Ounces Pressure and 2 Ounces Vacuum.

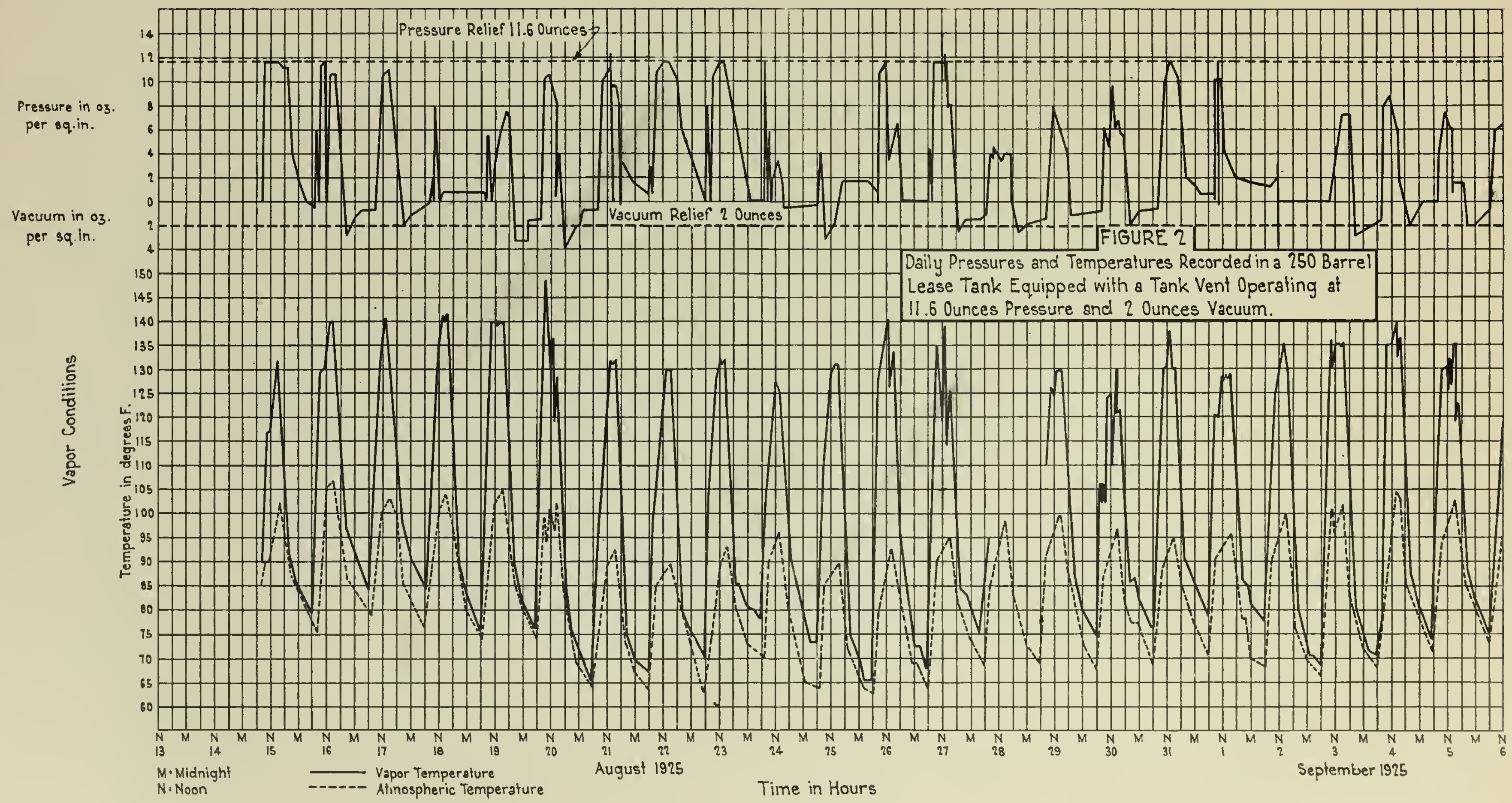


FIGURE 2

Daily Pressures and Temperatures Recorded in a 250 Barrel Lease Tank Equipped with a Tank Vent Operating at 11.6 Ounces Pressure and 2 Ounces Vacuum.

The evaporation losses sustained in this test are much below average, due to the low atmospheric temperatures and other winter conditions. During the summer months the losses would be at least twice those indicated by the test.

The results of this test and other tests on lease storage show that a tank equipped with a pressure relief valve, operating at 14 to 16 ounces pressure will reduce the evaporation losses about 60 per cent, as compared with a tank equipped with a relief valve holding about two ounces pressure, with other conditions equal.

The effect of pressure relief valves in reducing the amount of time the tank is breathing out is given in Figure 1, which shows the hourly temperatures and pressures of the vapor in a 250-barrel lease tank for a four-day period during the latter part of May 1926. This test probably represents average temperature conditions in the Mid-Continent area. The tank was equipped with a relief valve operating at 15.2 ounces pressure and 2 ounces vacuum. Figure 1 shows that on May 29, the tank vented to the atmosphere about 110 minutes. No venting took place on May 30 although the temperature in the vapor space reached 110°F. During the early morning hours of May 31 the temperature of the vapor space was 10°F. lower than the minimum reached the preceding day. This caused a considerable contracting of the vapor with the resultant flow of fresh air into the tank. For this reason the tank vented for a short period on May 31 although the maximum temperature was only 103°F., or 7°F. less than the preceding day. The minimum temperature was 5°F. lower than any preceding day recorded on the curve, and the maximum temperature was about 113°F. This resulted in the tank venting for about thirty minutes. This curve shows clearly the effect of temperature variation upon the breathing of the tank. It also indicates that if the tank had been equipped with a free vent, every small variation in temperature would have caused a movement of vapor, (either contraction or expansion) in the tank.

Figure 2 shows the pressures and temperatures developed, under operating conditions, in a 250-barrel lease tank equipped with a relief valve operating at 13.6 ounces pressure and 2 ounces vacuum. The data cover a period of 25 days. Gaging operations are shown by a rapid drop in pressure when the gage hatch is opened, and the rebuilding of the pressure after the gage hatch is closed, as at noon on August 16. Pipe-line gage, "turn on", and final gage are shown beginning with the gage and "turn on", August 18, and the final pipe-line gage and "turn off" for the morning of August 19. The filling operation is indicated by the excessive pressures developed on August 27.

The Effect of Light Colored Paints and Tank Houses

Although the value of light colored paints has been discussed in a previous report[2] it might be well to state two of the principal reasons for the use of light colored paint. First, light colored paint reduces the breathing of the tank by reducing the variations of the temperature of the vapor space. Second, it reduces the temperature of the vapor and the surface temperature of the oil. By lowering the surface temperature of the oil, the vapor pressure is reduced; this greatly reduces the breathing of the tank and the amount of gasoline vapor in the air-vapor mixture above the oil.

---

[2] Schmidt, Ludwig, "Effect of Tank Colors on Evaporation Loss of Crude Oil" Serial 2677, Bureau of Mines, 1925.

Tank houses reduce the evaporation losses in the same manner as light colored paints, that is, by reducing the breathing due to temperature variation and by reducing the vapor pressure of the crude. However, care must be exercised in the use of tank houses for this type of construction accelerates the flow of air around and over the tank, similar in action to a flue. If the tank is not vapor tight the use of the tank house probably will increase evaporation losses due to the increased circulation of air over the oil surface.

Relative Value of Light Colored Paints and Tank Houses

In order to determine the relative value of light colored paints and tank houses, three 250-barrel lease tanks, one painted with aluminum paint, one painted red, and the third protected by a wooden tank house were equipped with recording thermometers and observations were taken over an extended period of time. All of the tanks under observation were of the same make and equipped with a combination gage hatch and vacuum and pressure relief valve. In this valve the pressure relief is of the dead weight type, excessive pressure raising the entire cover allowing the air vapor mixture to vent through the gage hatch. The pressure valve operates at 16 ounces. The vacuum relief is operated by a vanadium steel spring which may be regulated to open at from 1/2 to 4 ounces of vacuum. In this test the vacuum valve was set to operate at 2 ounces. Before opening the gage hatch for sampling the oil or gaging, the pressure in the tank is released by pushing down the plunger in the center of the valve cover. This allows the excess air-vapor mixture to escape through the vacuum vent.

Crude Oil Used

The crude oil produced on this lease had an average gravity of about 36.3 A.P.I. with a gasoline and naphtha content of 29 per cent, determined by the Bureau of Mines Hempel method. A distillation record of the average crude is shown in Table 1.

Table 1 - Average Sample of Oil Used in Comparative Paint and Housed Tank Test

Air Distillation

Specific Gravity, 0.843 A.P.I. gravity, 36.3°

Per cent water, trace.

DISTILLATION, BUREAU OF MINES, HEMPEL METHOD

Air Distillation Barometer 745mm. First drop: 30°C. (86°F.)

Temperature °C	Per cent cut	Sum per cent	Sp.Gr. cut	A.P.I. cut	Temperature °F.
Up to 50	1.4	1.4)	0.655	84.5	Up to 122
50 - 75	1.4	2.8)			122 - 167
75 - 100	3.7	6.5	0.711	67.5	167 - 212
100 - 125	6.4	12.9	0.735	61.0	212 - 257
125 - 150	5.8	18.7	0.754	56.2	257 - 302
150 - 175	5.3	24.0	0.771	52.0	302 - 347
175 - 200	5.0	29.0	0.788	48.1	347 - 392
200 - 225	5.6	34.6	0.806	44.1	392 - 437
225 - 250	5.6	40.2	0.818	41.5	437 - 482
250 - 275	6.7	46.9	0.832	38.6	482 - 527

APPROXIMATE SUMMARY

	Per cent	Sp. Gr.	°A.P.I.
Light gasoline	6.5	0.687	74.5
Total gasoline and naphtha	29.0	0.744	58.7
Kerosene distillate	11.2	0.812	42.8
Gas oil	6.7	0.832	38.6

Discussion of Test

The comparative observations were started in March, 1926, and extended through October of the same year. The vapor temperatures in each tank were obtained with recording thermometers which were checked at intervals of four weeks. At these times, a general inspection of each tank was made to see that it was in first class condition and that no oil or dirt had collected on the tank that would effect the value of the different colored paints. All observations were made during the normal operation of the lease.

Results of Test

Observations made during the month of May were selected for discussion as they represent average conditions throughout the test period; these are shown in Table 2.

Table 2 - Comparative temperature data on three 250 barrel lease tanks operating under 16 ounces pressure, one painted red, one aluminum, and the third equipped with wooden tank-housing.

	Color of Tanks		Housed	Atmospheric
	Red	Aluminum	Tank	Temperature
Maximum Temperature in Degrees F	127°F	112°F	101°F	93°F
Minimum Temperature °F	52°F	44°F	45°F	40°F
Avg. daily maximum Temp.	108°F	92°F	89°F	82°F
Avg. daily minimum Temp.	60°F	57°F	63°F	58°F
Avg. daily temperature variation in vapor space	48°F	35°F	26°F	24°F
Avg. temperature of vapor	84°F	74.5°F	76°F	70°F
Estimated average daily increase of pressure due to thermal expansion of vapor in lbs. per sq. in.	1.32	1.09	.72	

Table 2 shows the average daily minimum temperature for the housed tank to be 63°F. This figure is the highest average daily minimum of the three tanks. An explanation for the comparatively high minimum temperature for the housed tank probably depends upon the laws of heat absorption. During the day the wood absorbs heat from the sun; at night the heat is given off slowly, and some of it is taken up by vapors in the tank. This action tends to retard the cooling. Also the housing prevents the cooling effect on the tank of occasional showers and of any dew or other moisture which collects on objects during the night.

The average daily increase of pressure due to the thermal expansion of the vapor as shown in table 1 was calculated from the average temperature variations and does not include the increase of pressure due to the increase of the vapor pressure of the crude oil, which is different for crude oils.

Actual evaporation tests were not made on these tanks. However, the gage tickets of the oil run from these tanks show the economic value of the aluminum, red, and housed tanks. The oil run varied in gravity from 35.6° A.P.I. to 36.7° A.P.I. the average being about 36° A.P.I. The gage tickets of oil run from each tank during the months of May, June, July, and August show that for the housed tank the average gravity was 36.34° A.P.I., with nine per cent of the oil run being under 36° A.P.I.; for the aluminum painted tank the average gravity was 36.21° A.P.I. with fourteen per cent of the oil run being under 36° A.P.I.; and the oil run from the red tank had an average gravity of 36° A.P.I. with 37.5 per cent under 36° A.P.I.

These records show conclusively the economic value of the light colors over dark colors for painting tanks; also the value of tank houses.

Although the housed tank showed best results in this test it should be kept in mind that installations must be made with care. First, if the tank is not kept vapor tight the housing acting similar to a flue, increases the circulation of air in the vapor space above the oil. Second, wood housing is inflammable and becomes a greater fire hazard as the boards become saturated with oil. Third, the space between the tank and housing often becomes a trash heap due to the accumulation of rags, waste, and other refuse, which gives the lease an unsightly appearance as well as increasing the fire hazard.

Conclusion

These tests indicate that it is doubtful if pressure alone or the use of light colored paints, or insulation alone will be the most economic methods of reducing the breathing losses from vapor tight tanks. It is probable that the most effective method will consist of a combination of light colored paints and the holding of suitable pressures on the tanks. The amount of pressure required depends upon the lease operation and the physical characteristics of the oil handled.

Acknowledgments

This investigation was conducted under the direction of the Bureau of Mines with the cooperation of the State of Oklahoma.

The Phillips Petroleum Company assisted in the preparation of this report by furnishing the oil and tanks for several of the field tests.

Ben E. Lindsly, acting superintendent; F. W. Lane, petroleum chemist; and E. L. Rawlins, associate natural gas engineer of the Bartlesville station of the Bureau of Mines, assisted in the preparation of the report with valuable suggestions and criticisms. Peter Grandone, junior chemist, and H. M. Thorne, assistant petroleum chemist, assisted in collecting the field data and made the distillations and gravity determination. The drawings were prepared by John Trevorrow and J. M. Seward of the Bartlesville Station. - Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un 32 mo
cop. 2

Serial No. 2835
October, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE--BUREAU OF MINES

THE LIBRARY OF THE
JUL 23 1928
UNIVERSITY OF ILLINOIS

COAL-MINE FATALITIES IN SEPTEMBER, 1927

By W. W. Adams[1]

Accidents at coal mines in the United States in September, 1927, resulted in the death of 158 men, according to reports furnished by State mine inspectors to the United States Bureau of Mines, Department of Commerce. As the output of coal in September was 48,592,000 tons, the fatality rate for the month was 3.25 per million tons mined, as compared with 3.13 for September last year, during which month there were 180 fatalities and 57,420,000 tons of coal produced. For bituminous mines alone the reports showed 129 lives lost and a fatality rate of 3.08 per million tons, based on an output of 41,950,000 tons, as compared with a rate of 2.74 for September last year, based on 48,976,000 tons of coal mined. The ten-year period from 1917 -- 1926 for September showed a fatality rate of 3.28 for bituminous coal mines. For anthracite mines alone, the number of deaths per million tons of coal produced was 4.37 for September; there were 29 deaths and 6,642,000 tons of coal mined during the month. September of last year showed 46 deaths in anthracite mines, 8,444,000 tons of coal and a fatality rate of 5.45.

Reports covering the first nine months of 1927 show a total of 1,638 lives lost in accidents at coal mines, as compared with 1,821 in the corresponding months of 1926. The fatality rate for 1927 to the end of September was 3.61 per million tons, as compared with 3.89 for the same period last year. For bituminous mines alone the average rate in 1927 for nine months was 3.24 as against 3.67 in 1926. For anthracite mines alone the nine-month average rate was 5.97 as compared with 5.35 for last year.

There were no major disasters -- that is disasters in which five or more lives are lost -- in September of this year, but the previous months showed 8 such accidents with a resulting loss of life of 155. The same period of last year showed 12 major disasters and 270 fatalities. The fatality rates per million tons for these two periods, based exclusively on major disasters, were 0.341 this year and 0.577 last year.

Comparing the principal causes of the fatal accidents in 1927 to the end of September with those for the same period last year, the records show a reduction in the death rates for falls of roof and coal, haulage, and gas or dust explosions, while a slight increase is noted for explosives and electricity.

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

These facts are shown in the following figures, which cover both anthracite and bituminous coal mines:

	Year 1926	Jan.-Sept. 1926	Jan.-Sept. 1927
All causes	3.790	3.894	3.606
Falls of roof and coal	1.829	1.835	1.776
Haulage	.650	.684	.559
Gas or dust explosions:			
Local explosions	.111	.126	.127
Major explosions	.525	.577	.326
Explosives	.145	.137	.183
Electricity	.143	.154	.176

Tables 1 to 4 inclusive, present a detailed statistical comparison of the number and causes of accidents and corresponding rates in 1927 with similar figures for earlier years. Table 5 shows the number of men killed and injured per 1,000 300-day workers employed in mineral industries. Table 6 shows the death rates per 1,000 300-day workers for coal mines in Great Britain and in the United States for the years 1921 to 1925 inclusive. The figures for Great Britain relate to mines under the Coal Mines Act, which means about 95 per cent coal and about 5 per cent other minerals. The underground rates are based on underground employees and the total rates are based on total employees underground and surface combined.-- Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE 1 - NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES
(Includes both anthracite and bituminous coal)

	Year 1926	Jan.-Sept. 1926	Jan.-Sept. 1927
Falls of Roof & Coal	1.829	1.835	1.776
At face	1.336	1.420	1.321
In room	.238	.216	.233
On entry	.193	.195	.211
On slope	.012	.004	.011
Haulage	.650	.684	.559
Switching and spragging	.020	.017	.007
Coupling	.008	.009	.024
Falling from trips	.030	.021	.033
Run over	.241	.254	.229
Caught between car and rib	.136	.154	.143
Caught between car and roof	.027	.026	.031
Runaway cars	.057	.058	.053
Miscellaneous	.131	.145	.039
Gas or Dust Explosions	.636	.703	.453
Open light	.191	.126	.075
Defective safety lamp	.005	.006	.002
Electric arc	.081	.105	.053
Shot	.077	.103	.026
Powder explosion	.005	.006	.002
Miscellaneous	.277	.357	.295
Explosives	.145	.137	.183
Transportation	-----	-----	.002
Charging	.006	.009	.004
Suffocation	.008	.004	-----
Drilling into old holes	.003	.002	-----
Striking in loose rocks	-----	-----	-----
Thawing	-----	-----	-----
Caps & detonators	.001	.002	.007
Unguarded shots	.006	.004	.007
Returned too soon	.013	.015	.013
Premature shot	.048	.045	.073
Sparks from lamp, etc	.005	.006	.007
Delayed shots	.015	.013	.013
Shot breaking through rib	.011	.011	.020
Miscellaneous	.029	.026	.037
Electricity	.143	.154	.176
Direct contact with trolley wire	.050	.047	.066
Tools striking trolley wire	.003	.004	.004
Contact with mining machine	.013	.009	.020
Contact with machine feed wire	.009	.009	.026
Contact with haulage motor	.003	.004	-----
Miscellaneous	.065	.081	.060

TABLE 2 - COAL-MINE FATALITIES DURING SEPTEMBER, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																													
Falls of roof	3	-	-	1	1	2	-	1	10	-	-	-	1	1	-	2	2	17	-	1	-	1	3	1	20	1	68	13	81
Falls of side	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	1	7	5	12
Haulage	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	7	-	-	-	-	-	-	10	-	20	1	21
Gas or dust explosions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	1	3
Explosives	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	4	6
Suffocated by mine gases	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	-	2
Electricity	2	-	-	1	1	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	8	-	8
Animals	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Mining machines	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	2
Mine fires	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other cases	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	4
TOTAL	5	-	-	4	2	3	-	1	15	1	-	1	1	2	-	3	2	28	-	1	2	1	3	1	35	2	113	27	140
SHAFT																													
Persons falling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Objects falling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cages, skips	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	1
Other causes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1
TOTAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	2	-	2
SURFACE																													
Mine cars	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	3	-	3
Electricity	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	2
Machinery	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3	-	3
Boiler explosions	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Railway cars	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	1	-	5	2	7
TOTAL	1	-	-	-	1	1	-	1	1	-	-	-	-	-	-	1	1	2	-	-	-	-	-	-	5	-	14	2	16
GRAND TOTAL, Sept., 1927	6	0	0	4	3	4	0	2	16	1	0	1	1	2	0	5	3	30	0	1	2	1	3	1	41	2	129	29	158
GRAND TOTAL, Sept., 1926	7	0	0	1	13	6	2	1	10	4	0	2	1	1	0	7	17	22	0	1	0	3	3	0	32	1	134	45	180

TABLE 3 - COAL-MINE FATALITIES DURING 1927 and 1926, BY MONTHS AND STATES.

MONTH	Alas	Alas	Ark	Col	Ga. & N.C.	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	W Va	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January..............	6	-	2	8	-	19	3	1	-	23	-	1	1	1	2	-	7	2	35	-	3	-	1	2	1	43	4	165	46	211
February.............	7	-	2	5	-	11	5	1	2	10	-	-	-	1	2	2	9	2	31	-	-	-	5	5	2	35	-	138	41	179
March................	6	-	-	7	-	23	7	1	2	6	-	-	-	-	2	-	6	2	35	-	3	-	2	3	1	38	1	145	42	187
April................	6	-	-	2	-	4	-	2	-	2	-	1	-	1	-	-	3	2	33	-	1	-	3	3	7	144	-	214	41	255
May..................	6	-	1	8	-	4	-	1	-	11	-	-	-	-	1	-	5	1	25	-	-	-	3	9	2	50	1	128	53	181
June.................	4	-	1	3	-	-	2	-	1	5	1	-	-	2	3	-	3	2	29	-	-	-	2	1	1	53	1	114	52	166
July.................	11	-	1	1	-	-	1	-	1	17	1	-	-	-	-	-	5	3	24	-	3	-	1	-	1	34	1	105	30	135
August...............	9	-	1	4	-	2	1	2	1	30	-	-	-	1	2	-	3	-	34	-	3	-	1	5	1	35	5	140	26	166
September............	6	-	-	4	-	3	4	-	2	16	1	-	1	1	2	-	5	3	30	-	1	2	1	3	1	41	2	129	29	158
TOTAL, 9 months, 1927.	61	-	8	42	-	66	24	8	9	120	3	2	2	7	14	2	46	17	276	-	14	2	19	31	17	473	15	1,278	360	1,638
TOTAL, 9 months, 1926.	110	1	3	36	1	108	29	7	12	133	11	1	4	3	12	1	58	120	306	0	18	0	16	36	6	442	19	1,493	328	1,821
TOTAL, 1926.....	139	1	7	53	3	166	78	16	17	178	12	1	9	5	13	1	80	124	420	0	50	0	20	58	15	573	22	2,061	453	2,514

TABLE 4 - AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED

Cause of accident	Per cent of total 1917-1926	Death rates per million short tons						
		Average for 10 years 1917-1926	Year 1925	Year 1926	Average for Sept. 10 years 1917-1926	1927		1926
						Aug.	Sept.	Sept.
		Bituminous Mines						
1. Falls of roof and coal	48.96	1.759	1.750	1.717	1.744	1.918	1.788	1.449
2. Underground haulage.	18.18	.653	.586	.655	.597	.455	.477	.572
3. Explosions of gas or coal dust:								
Local explosions	2.91	.104	.112	.080	.057	.024	.048	- - -
Major explosions	10.84	.390	.469	.565	.198	.360	- - -	.327
4. Explosives	3.30	.118	.094	.080	.133	.048	.048	- - -
5. Electricity.	4.01	.144	.154	.161	.168	.192	.190	.163
6. Mining machines.	1.33	.048	.067	.045	.037	.096	.048	.020
7. Other causes underground . . .	2.93	.105	.089	.067	.087	.096	.095	.082
8. All causes underground	92.46	3.321	3.321	3.370	3.021	3.189	2.694	2.613
9. All shaft accidents.	1.73	.062	.058	.047	.087	.048	.048	.082
10. All accidents on surface . . .	5.81	.209	.148	.147	.172	.120	.333	.041
11. All accidents.	100.00	3.592	3.527	3.564	3.280	3.357	3.075	2.736
		Anthracite Mines						
1. Falls of roof and coal	42.71	2.496	2.750	2.588	1.927	1.549	2.710	2.369
2. Underground haulage.	12.75	.745	.906	.612	.721	.387	.151	.592
3. Explosions of gas:								
Local explosions	6.71	.392	.421	.329	.436	.258	.151	.829
Major explosions	1.51	.088	.275	.247	- - -	- - -	- - -	- - -
4. Explosives	12.37	.723	.857	.588	.620	.387	.602	.829
5. Electricity.	1.00	.059	.065	.024	.134	.129	- - -	- - -
6. Other causes underground . . .	8.18	.478	.323	.459	.486	.129	.451	.592
7. All causes underground	85.23	4.981	5.597	4.847	4.324	2.839	4.065	5.211
8. All shaft accidents.	2.30	.134	.065	.094	.117	.129	- - -	- - -
9. All accidents on surface . . .	12.47	.729	.809	.388	.587	.387	.301	.237
10. All accidents.	100.00	5.844	6.471	5.329	5.028	3.355	4.366	5.448

TABLE 5 - United States: Number of men killed and injured per 1,000 300-day workers employed in mineral industries

Mineral industries	Killed					Injured				
	1921	1922	1923	1924	1925	1921	1922	1923	1924	1925
Coal mines (1)	4.20	4.90	4.39	4.80	4.65	---	---	---	---	---
All metal mines	3.09	3.54	3.01	3.51	2.99	249.68	268.48	275.41	278.04	283.53
Copper mines	3.70	3.00	3.11	3.55	2.94	317.53	320.78	349.09	347.82	350.62
Gold and miscellaneous metal mines	3.29	5.35	3.93	4.99	3.83	225.46	260.29	298.87	297.80	307.42
Iron mines	3.04	3.00	2.38	2.95	2.54	210.91	177.44	150.23	151.01	159.43
Lead and zinc mines (Mississippi Valley)	2.58	2.64	2.73	2.76	3.32	379.67	464.23	495.65	464.16	468.07
Nonmetallic mineral mines	1.98	2.39	2.67	1.94	1.71	215.47	247.51	212.47	178.74	165.40
All quarries (including outside works)	2.00	1.92	1.68	1.63	1.78	174.54	171.93	176.04	175.03	169.67
Cement-rock quarries	1.91	2.27	1.67	2.26	1.78	213.50	191.08	213.71	169.13	103.55
Granite quarries	2.57	1.42	.90	1.19	.96	134.09	147.20	177.99	195.73	202.52
Limestone quarries	1.97	1.87	1.87	1.64	1.76	178.54	177.72	169.30	173.58	193.47
Marble quarries	1.49	.43	.59	1.22	.56	100.87	127.76	127.88	131.89	116.04
Sandstone and bluestone quarries	1.25	1.19	.48	1.88	3.32	156.22	100.63	119.42	169.09	200.31
Slate quarries	1.40	3.15	2.13	.57	2.60	135.18	127.40	149.11	159.98	168.98
Trap-rock quarries	2.88	3.36	3.35	1.84	4.13	229.92	258.01	228.47	234.39	324.87
All quarries (excluding outside works)	2.22	2.31	1.97	1.90	2.28	167.09	177.16	178.11	178.00	195.02
All quarries (outside works only)	1.68	1.38	1.26	1.24	1.22	185.79	164.76	173.05	170.61	141.06
Metallurgical plants:										
Ore-dressing plants	.50	1.09	1.62	1.24	1.00	151.05	179.51	172.44	156.03	130.56
Smelters	.99	.77	.64	.55	.64	149.89	143.71	130.71	112.65	113.83
Auxiliary works	1.08	1.21	.94	1.08	.41	138.54	120.26	132.37	137.43	107.96
All coke ovens	1.23	1.59	1.76	1.16	1.16	133.62	93.77	101.18	79.54	70.51
Beehive coke ovens	1.76	1.66	1.68	.75	.78	118.52	98.28	122.48	113.54	96.89
By-product coke ovens	1.09	1.57	1.79	1.26	1.27	137.50	92.15	92.95	71.33	63.34

(1) Injury rates not available.

TABLE 6 - Number of men killed per 1,000 300-day workers employed in mineral industries in Great Britain and the United States.[1]

	Roof & Coal	Haulage	Explosions Gas or Dust	All U. G. & Shaft	Total including surface
Great Britain:					
1921........	0.68	0.30	0.03	1.21	1.08
1922........	.68	.26	.09	1.23	1.09
1923........	.65	.35	.07	1.30	1.15
1924........	.70	.30	.04	1.25	1.10
1925........	.73	.35	.04	1.37	1.21
United States: (bituminous only)					
1921........	2.77	.96	.22	4.83	4.38
1922........	2.82	1.02	1.08	5.73	5.16
1923........	2.65	.95	.92	5.19	4.65
1924........	2.79	.98	1.60	6.00	5.39
1925........	2.76	.92	.92	5.33	4.79
United States: (anth. & bitum.)					
1921........	2.60	.86	.32	4.75	4.20
1922........	2.72	1.02	.93	5.53	4.90
1923........	2.51	.89	.80	4.96	4.39
1924........	2.54	.85	1.28	5.42	4.80
1925........	2.69	.90	.86	5.24	4.65

---

[1] Underground rates are based on underground workers; total rates are based on all workers, above ground as well as underground. Figures for Great Britain relate to all mines under the Coal Mines Act.

Serial No. 2836
October, 1927.

622.09
Un 32 mo
cop. 2

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

THE LIBRARY OF THE
JUL 2 3 1959
UNIVERSITY OF ILLINOIS

CONSUMPTION OF EXPLOSIVES IN SEPTEMBER, 1927

By W. W. Adams[1]

Sales of explosives in the United States in September, 1927, amounted to 475,300 kegs (11,882,500 pounds) of black blasting powder, 5,680,000 pounds of permissible explosives, and 27,559,000 pounds of high explosives other than permissibles. These figures are based upon reports from manufacturing companies to the United States Bureau of Mines, Department of Commerce, and include an estimate of sales by several companies that do not report monthly. Reports actually received from the manufacturers showed sales of 465,776 kegs of powder, 5,671,874 pounds of permissibles, and 25,894,499 pounds of other high explosives. All three classes of explosives showed reductions in quantities sold in September 1927 as compared with September 1926. The reductions amounted to 17 per cent for black blasting powder, 8 per cent for permissibles, and 4 per cent for high explosives other than permissible.

PERMISSIBLE EXPLOSIVES: Sales of permissible explosives in September brought the total sales during the first nine months of 1927 to 47,425,000 pounds, including 47,354,762 pounds actually reported and an estimate to cover sales by several non-reporting companies. The quantity sold in the nine-month period January to September 1927 was slightly more than that sold during the same period in 1926. Nearly 96 per cent of the explosives were for use in coal mines, 67 per cent being for bituminous mines and 29 per cent for anthracite mines. The quantity used at bituminous mines during the nine months January to September has averaged 80 pounds of permissibles, or 29 per cent of the 272 pounds of all kinds of explosives per thousand tons of bituminous coal produced. The corresponding record for anthracite mines shows 751 pounds of all kinds of explosives per thousand tons of coal produced, of which 229 pounds, or 31 per cent, were permissibles. During the first nine months of 1927, the largest quantities of permissibles were used in the States of Pennsylvania, West Virginia, Alabama, Kentucky, and Illinois. The combined sales for use in these large coal-producing States represented 88 per cent of the entire amount of permissibles sold.

BLACK BLASTING POWDER: The amount of black blasting powder sold during the period January to September 1927 was 3,810,500 kegs, including 3,734,326 kegs sold by reporting companies and an estimate of sales by non-reporting companies. There was a decrease of 13 per cent in the sales for this period in 1927 as compared with the same nine-month period in 1926. Eighty-four per cent of the total quantity was sold for use in coal mines, 73 per cent being for bituminous mines and 11 per cent for anthracite mines.

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

The quarrying industry used 5 per cent and an equal amount was used in railway and other construction work. Metal mining and miscellaneous purposes used 6 per cent. In the coal-mining industry, the consumption of black blasting powder since January first has averaged 176 pounds, or 65 per cent, of a total of 272 pounds of all kinds of explosives per thousand tons of bituminous coal produced, while in the anthracite mines the average consumption of black powder was 182 pounds, or 24 per cent, of the 751 pounds of all classes of explosives used for each thousand tons of coal produced. States using the largest amounts of this class of explosives during the past nine months are Pennsylvania, Kentucky, West Virginia, Illinois, Indiana, and Ohio. These six States received 70 per cent of the entire volume of sales during the 9-month period January to September, 1927.

OTHER HIGH EXPLOSIVES: Sales of high explosives other than permissibles brought the total sales of this class of explosives during the first nine months of 1927 to 233,640,000 pounds, a decrease of 1 per cent in comparison with the quantity sold during the same period in 1926. Sales during 1927 include 219,527,705 pounds actually reported to the Bureau of Mines and an estimate of sales by several companies that do not furnish monthly reports. Metal mining was the largest consumer of this class of explosives during the nine-month period, the consumption amounting to 30 per cent of the total quantity sold; while quarrying and nonmetallic mineral mining used 28 per cent; coal mining used 12 per cent (9 per cent by anthracite mines and 3 per cent by bituminous mines); and railway and other construction work 16 per cent. The remaining 14 per cent was used for miscellaneous purposes. The amount used at anthracite mines since January first has averaged 340 pounds per thousand tons of coal produced, or 45 per cent of the 751 pounds of all kinds of explosives per thousand tons. The corresponding nine-months' consumption at bituminous coal mines was 16 pounds of high explosives, or 6 per cent of the 272 pounds of all kinds of explosives used per thousand tons of coal produced. The following States have used more than six million pounds of "high" explosives during the past nine months: Pennsylvania, Michigan, California, New York, Minnesota, Ohio, Oklahoma, Florida, Missouri, Texas, Washington, Alabama and Utah. The combined sales to these States represent 66 per cent of the entire sales of this class of explosives.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in September were more than 362,000 kegs, showed that the mills were operated to 49 per cent of their capacity in September as compared with 45 per cent in August, 37 per cent in July, and 43 per cent in September last year and 42 per cent for the first nine months of 1927. During the first nine months of 1926 the mills were operated to 38 per cent of their capacity.

	September, 1926	September, 1927	Jan.-Sept., 1927
Capacity (Kegs)..........	955,583	796,083	7,164,747
Manufactured.............	409,120	392,889	2,986,618
Per cent of capacity.....	43	49	42
Shipments................	433,338	360,067	2,940,813
Per cent of capacity.....	45	45	41
Sales....................	419,724	362,391	2,873,079
Per cent of capacity.....	44	46	40
Stocks, end of month.....	412,935	447,225	447,225
Per cent of capacity.....	43	56	6.2

The following percentage figures show the extent of capacity to which mills manufacturing black powder were operated in 1924, 1925, 1926, average for nine months in 1926 and in the months of January to September, 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month.

	Manufactured	Shipments	Sales	Stocks
Year 1924...............	41	41	41	3.8
Year 1925...............	38	39	38	3.2
Year 1926...............	40	40	39	3.6
Average, 9 mos. 1926.....	38	37	37	4.8
1927				
January..................	54	55	56	50
February.................	54	47	45	58
March....................	36	36	38	58
April....................	31	32	30	57
May......................	29	36	35	49
June.....................	40	37	33	52
July.....................	37	36	34	53
August...................	45	45	44	52
September................	49	45	46	56
Average, 9 months........	42	41	40	6.2

Reports from 23 mills that sold more than 26 million pounds of permissibles and other high explosives in September showed that the mills were operated to 66 per cent of their capacity in September as compared with 67 per cent in August, 58 per cent in July, and 77 per cent in September last year, and 65 per cent average for the first nine months of 1927. During the first nine months of 1926 the mills were operated to 68 per cent of their capacity. The amount of explosives remaining on hand at the close of September represented 15 per cent of one month's manufacturing capacity of the mills reporting, as compared with 16 per cent at the close of September a year ago.

	September, 1926	September, 1927	Jan-Sept.,19
Capacity (Pounds)........	39,528,532	40,945,000	357,755,000
Manufactured.............	30,512,604	27,036,122	231,120,805
Per cent of capacity.....	77	66	65
Shipments................	30,264,557	27,962,540	231,779,718
Per cent of capacity.....	77	68	65
Sales....................	27,855,020	26,244,713	222,458,307
Per cent of capacity.....	70	64	62
Stocks, end of month.....	6,164,678	5,971,665	6,898,592
Per cent of capacity.....	16	15	1.9

The percentage of full-time capacity to which mills manufacturing permissibles and other explosives were operated in 1924, 1925, 1926, average for nine months in 1926, and in the months of January to September, 1927, is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining on hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924...............	62	62	59	1.4
Year 1925...............	62	62	59	1.5
Year 1926...............	68	68	64	1.4
Average, 9 mos. 1926.....	68	68	64	1.7
1927				
January..................	59	58	57	19
February.................	63	62	57	20
March....................	64	64	62	20
April....................	66	69	65	17
May......................	73	72	69	18
June.....................	65	66	64	17
July.....................	58	58	58	15
August...................	67	66	63	17
September................	66	68	64	15
Average, 9 months........	65	65	62	1.9

PYROTOL: During the first nine months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 13,767,660 pounds of pyrotol of which 1,669,850 pounds represented shipments in September. During the corresponding nine months last year the shipments amounted to 12,368,750 pounds. Most of the pyrotol shipped was for use by farmers in clearing land. Table D shows the amount of pyrotol shipped to each State in September, 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal-mining operations in each State from January to September, 1927, is shown in Table C. Table D shows the quantity of pyrotol distributed in September to the various States.--Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE A - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during September, 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	8,999	616,900	359,850
Alaska	50	327,400	4,000
Arizona	1,800	126,800	-
Arkansas	8,291	191,856	21,200
California	8,609	1,853,510	2,050
Colorado	8,932	478,010	87,550
Connecticut	-	141,100	-
Delaware	30	4,400	-
Florida	3,400	645,525	-
Georgia	1,736	110,200	-
Idaho	1,701	432,640	-
Illinois	42,961	693,855	256,300
Indiana	48,934	522,475	152,075
Iowa	6,344	354,575	1,000
Kansas	16,719	679,922	17,600
Kentucky	63,192	527,775	282,725
Louisiana	-	498,628	-
Maine	57	97,800	-
Maryland & D.C.	1,058	223,450	19,150
Massachusetts	158	143,550	-
Michigan	10	1,630,825	-
Minnesota	4,083	1,193,025	-
Mississippi	40	163,575	-
Missouri	7,295	842,850	25,350
Montana	9,223	453,835	2,000
Nebraska	43	18,950	-
Nevada	2,500	269,225	-
New Hampshire	18	13,250	-
New Jersey	1	282,650	-
New Mexico	970	81,650	23,000
New York	1,479	1,221,900	11,500
N. Carolina	3,644	397,400	500
N. Dakota	3,430	2,700	2,000
Ohio	30,241	1,285,950	73,950
Oklahoma	9,476	979,435	58,049
Oregon	609	337,150	-
Pennsylvania	85,223	3,982,669	2,654,300
Rhode Island	34	8,150	-
S. Carolina	285	54,970	-
S. Dakota	64	172,235	-
Tennessee	7,327	239,525	15,600
Texas	6,482	565,390	-
Utah	2,004	736,450	79,500
Vermont	811	17,850	-
Virginia	7,702	245,575	77,500
Washington	2,623	850,019	80,400
West Virginia	54,130	588,300	1,241,475
Wisconsin	101	470,225	-
Wyoming	2,857	118,400	123,250
TOTAL SEPTEMBER 1927	465,776	25,894,499	5,671,874

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first nine months of 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	83,150	6,382,469	3,699,050
Alaska	371	1,800,090	62,700
Arizona	16,765	1,257,100	-
Arkansas	46,581	1,235,047	110,933
California	63,575	13,900,298	2,050
Colorado	43,409	4,031,576	636,250
Connecticut	346	1,192,800	-
Delaware	32	60,799	-
Florida	21,614	7,528,497	-
Georgia	12,843	1,404,375	-
Idaho	5,832	3,139,208	8,850
Illinois	388,154	5,996,757	1,302,375
Indiana	349,680	3,175,660	500,925
Iowa	70,325	2,160,250	5,450
Kansas	129,975	5,682,881	188,115
Kentucky	524,761	3,823,580	2,593,350
Louisiana	350	2,231,139	73,300
Maine	1,520	563,650	-
Maryland & D.C.	19,128	1,805,250	124,650
Massachusetts	1,279	961,175	-
Michigan	6,428	15,708,175	1,200
Minnesota	32,013	9,920,577	-
Mississippi	2,101	1,064,125	-
Missouri	58,313	7,391,457	126,981
Montana	45,647	4,771,477	19,950
Nebraska	1,523	146,750	-
Nevada	26,856	2,541,250	200
New Hampshire	342	131,550	-
New Jersey	62	2,574,375	-
New Mexico	12,696	472,175	231,300
New York	10,354	11,443,424	41,900
N. Carolina	24,237	2,966,275	8,250
N. Dakota	13,587	91,057	11,975
Ohio	193,428	8,862,145	210,150
Oklahoma	82,851	8,395,342	217,383
Oregon	17,795	3,119,775	250
Pennsylvania	739,974	35,025,418	23,613,590
Rhode Island	139	76,950	-
S. Carolina	2,652	594,045	-
S. Dakota	481	1,008,800	1,300
Tennessee	84,784	2,868,570	248,950
Texas	63,231	6,831,545	38,850
Utah	14,630	6,220,665	652,145
Vermont	2,972	311,450	-
Virginia	51,845	2,858,700	964,090
Washington	32,479	6,477,807	492,525
West Virginia	406,277	4,237,700	10,497,375
Wisconsin	3,667	4,030,925	50
Wyoming	23,272	1,052,600	668,350
TOTAL 1st 9 MOS. 1927	3,734,326	219,527,705	47,354,762

SEPTEMBER, 1927

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs	Pounds	Pounds
Quantity used for:			
Coal mining....................	394,480	3,114,550	5,366,024
Metal mining...................	7,781	7,513,608	31,150
Quarrying and nonmetallic mineral mining...............	22,279	7,020,405	62,250
Railway and other construction work.........................	20,373	4,365,449	14,675
All other purposes............	20,363	3,880,487	197,775
TOTAL SEPTEMBER 1927............	465,776	25,894,499	5,671,874

JANUARY TO SEPTEMBER, 1927, INCLUSIVE

	Black blasting powder	High explosives other than permissible	Permissible explosives
Quantity used for:			
Coal mining....................	3,141,125	25,355,959	45,299,088
Metal mining...................	69,750	66,623,460	109,125
Quarrying and nonmetallic mineral mining...............	182,673	61,993,463	407,620
Railway and other construction work.........................	190,795	36,022,086	165,286
All other purposes............	149,983	29,532,737	1,373,643
TOTAL 1st 9 MOS. 1927............	3,734,326	219,527,705	47,354,762

TABLE C - Quantity of explosives sold for use in COAL MINES in September 1927 [a]
by manufacturers rendering monthly reports

(Including cumulative figures for the first nine months of 1927)

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama.......	7,673	64,900	52,200	458,844	355,050	3,671,250
Arkansas......	8,260	45,872	25,550	67,250	3,700	15,383
Colorado......	6,587	31,143	40,200	163,525	82,150	583,400
Illinois......	41,851	382,030	43,800	310,450	337,100	1,196,550
Indiana.......	48,542	343,828	161,175	710,350	143,775	461,000
Iowa..........	6,243	67,285	7,325	79,325	1,000	4,000
Kansas........	15,908	123,493	73,875	494,951	13,750	182,465
Kentucky......	57,669	497,124	68,200	746,600	280,125	2,393,550
Maryland......	800	15,226	2,900	41,000	14,000	71,350
Michigan......	10	4,927	7,200	40,500	-	-
Missouri......	4,149	40,832	23,400	124,550	2,300	30,531
Montana.......	8,104	34,100	2,650	13,200	2,000	9,950
New Mexico....	900	3,705	1,000	20,600	23,000	219,050
North Dakota..	3,354	13,220	600	56,475	2,000	11,975
Ohio..........	25,826	164,167	45,200	328,700	700	55,850
Oklahoma......	8,480	73,703	3,850	97,350	39,699	170,574
Penna.(Bitum.)	25,644	258,822	105,425	1,011,608	992,000	9,435,495
Tennessee.....	4,936	70,712	12,050	123,300	15,150	230,650
Texas.........	2,970	18,123	-	5,700	-	-
Utah..........	-	-	1,050	35,300	74,500	636,145
Virginia......	5,913	41,642	15,450	177,250	72,900	948,590
Washington....	141	9,902	2,650	61,300	39,600	324,250
West Virginia.	51,608	385,978	114,300	782,550	1,225,275	10,139,125
Wyoming.......	2,726	13,071	2,700	40,350	105,250	568,400
Other States..	1,635	7,665	3,500	81,475	2,500	77,350
Total (Bitum.)	339,928	2,711,470	816,750	6,072,503	3,727,524	31,492,863
Penna. (Anth.)	54,552	429,655	2,297,800	19,283,456	1,638,500	13,806,225
Grand Total as reported...	394,480	3,141,125	3,114,550	25,355,959	5,366,024	45,299,088
Est. total inc. non-reporting companies	Anth.	438,600		20,514,000		13,824,000
	Bitum.	2,766,800		6,472,000		31,538,000
Total reported plus estimate..		3,205,400		26,986,000		45,362,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period September 1, 1927 to September 30, 1927.

State	State Highway Department Roads	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
Alabama..............	2,000	-	-	-	2,000
California...........	-	-	-	21,000	21,000
Indiana..............	-	20,000	-	-	20,000
Iowa.................	-	65,000	-	-	65,000
Kansas...............	1,500	-	-	-	1,500
Michigan.............	-	110,550	-	-	110,550
Minnesota............	7,000	220,000	-	-	227,000
Mississippi..........	20,000	-	-	-	20,000
Montana..............	-	-	5,000	-	5,000
Nebraska.............	-	33,700	-	300	34,000
North Carolina.......	-	74,400	-	-	74,400
Oregon...............	7,500	132,650	4,000	3,000	147,150
South Carolina.......	-	19,300	-	-	19,300
Utah.................	-	-	5,000	-	5,000
Washington...........	87,000	265,000	-	46,000	398,000
Wisconsin............	-	509,950	-	-	509,950
Wyoming..............	-	-	10,000	-	10,000
Total September......	125,000	1,450,550	24,000	70,300	1,669,850
Total August.........	199,500	220,250	336,400	24,000	780,150
Total July...........	140,850	444,000	122,000	20,000	726,850
Total June...........	225,300	685,250	108,300	72,900	1,091,750
Total May............	162,000	825,500	26,000	352,100	1,365,600
Total April..........	281,550	1,669,550	7,500	222,000	2,180,600
Total March..........	249,500	1,916,860	-	108,700	2,275,060
Total February.......	170,750	1,020,150	-	-	1,190,900
Total January........	93,000	704,050	-	20,000	817,050
Grand Total..........	1,772,450	10,386,710	648,200	960,300	13,767,660

622.09
Un32mo
cop.2

Serial No. 2837 -50
November, 1927.

THE LIBRARY OF THE
JUL 23
UNIVERSITY OF ILLINO

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

THE STUDY OF AN INTERMEDIATE BASE CRUDE OIL[1]

By H. M. Smith[2]

Introduction

Although the study of the high-boiling compounds and the non-volatile compounds present in crude petroleum has been almost neglected, it is one of the most interesting problems of petroleum chemistry. These compounds fall into two main groups; those that are liquid at room temperature, including the hydrocarbons that make up lubricating oil, and those that are solid, such as the waxes and asphalts.

Considerable work has been done by Young, Mabery, and others on the hydrocarbons in crude petroleum. However, the major part of their work has been on compounds containing ten or less carbon atoms, and our knowledge of these hydrocarbons is much more definite than the available information on the less volatile constituents. There is, indeed, as Dunstan and Thole[3] very aptly state, "Profound ignorance of the chemistry of the high boiling components of petroleum."

These less volatile portions, when used commercially, are evaluated through determinations of certain physical properties such as viscosity, specific gravity, boiling and melting points, but the relations that these properties bear to the chemical constitution of the oils are virtually unknown. Realizing this, the Bureau of Mines is making a study of that portion of crude oil which has a boiling point of 300°C. or above, and which is liquid at 0°C. While these limits are quite arbitrary, they include practically all the material used in the manufacture of lubricating oils which is obtained from petroleum.

This paper summarizes the results obtained from studying the lubricants from a so-called typical intermediate base crude. A full report of this investigation will shortly be published by the bureau as a technical paper.

---

[1] - Presented at meeting of American Chemical Society, Detroit, Sept. 6, 1927. Published by permission of the Director, Bureau of Mines, Department of Commerce. Not subject to copyright.

[2] - Assistant Petroleum Chemist, Bureau of Mines, Petroleum Experiment Station, Bartlesville, Oklahoma.

[3] - Dunstan, A. E., and Thole, F. B. - The Relation between Viscosity and the Chemical Constitution of Lubricating Oils. J. Inst. Pet. Tech. Vol. 4, 1918, p. 191.

Source of Material

Crude oil from the Salt Creek, Wyoming field was selected as a source of material. This crude was chosen for several reasons; first, because the bureau was able to obtain an ample supply of this petroleum on which accurate sampling data were available; second, because Salt Creek crude is typical of the oil produced not only in a large part of the Rocky Mountain district, but also in a large part of the Mid-Continent; third, because the bureau had already made a semi-commercial analysis of this crude oil.

Scope of Investigation

The present investigation consists of two parts: (1) The separation of the crude into three main fractions;--gasoline, less volatile liquids, and solids; (2) a detailed study of the less volatile liquid fractions. The methods used in the separation of the three fractions are given below.

Experimental Methods

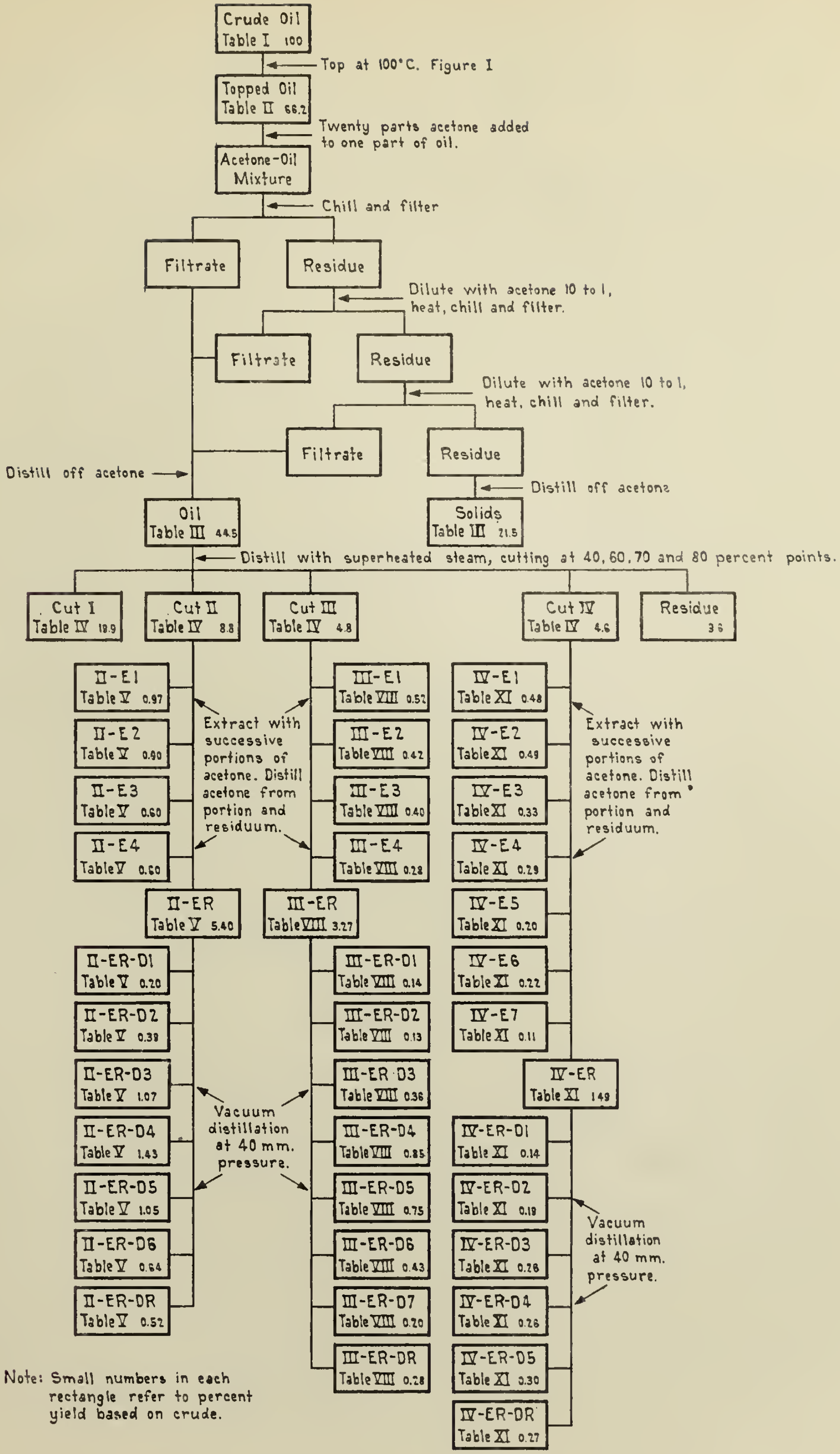
One prerequisite for any study of the compounds actually present in petroleum is the preparation of samples with a minimum amount of change or decomposition. The necessity and difficulties of meeting this prerequisite have led to a large number of diverse ways for separating the components of petroleum.

After careful consideration of the methods which might be used, it was thought that a combination of several would prove most advantageous. Those which were utilized in obtaining the samples studied are briefly described here. The gasoline was first removed from the crude by a modified gas distillation. This topped oil was then dewaxed by means of acetone, and the resultant oil, after the removal of the solvent, was steam distilled, and the distillate divided into four cuts as shown in Table I.

TABLE I - Steam Distillation

Cut	Topped and dewaxed oil	Crude	Viscosity 38°C. (100°F)		Sp.Gr.	A.P.I.	Column Temp.	
	Per cent	Per cent	Say.	Abs.*	15.5°C. 60°F.	15.5°C. 60°F.	°C	°F
I	37.8	16.9	38	2.9	0.837	37.6	174	345
II	19.5	8.8	53	6.8	.867	31.7	195	383
III	10.6	4.8	94	16.1	.891	27.3	213	416
IV	10.3	4.6	264	50.9	.917	22.8	257	495

* Centipoises.



Note: Small numbers in each rectangle refer to percent yield based on crude.

FIGURE 1

DETAIL FLOW SHEET

The residuum was discarded, as it was a very sticky, semi-solid material and apparently did not contain any lubricating stock of value for this work.

The low viscosity of Cut I indicates that it is composed largely of kerosene and gas oil, and the temperature at which the cut was made would very probably compare to a temperature below 300°C. at atmospheric pressure. The lubricating stock from this crude therefore is contained in Cuts II, III, and IV.

Fractional Solution.- As a means of further fractionating these cuts, the selective solvent action of acetone was again used, this time by fractional solution in the following manner: a portion of the cut, together with an equal amount of acetone, was placed in a covered glass jar provided with a stirrer. The jar was then immersed in a bath of ice and water kept at approximately 1° - 2°C. (35°F.) and vigorously stirred for several hours. The mixture was then transferred to a graduate and allowed to stand at the same temperature until the supernatent acetone solution became clear, after which it was siphoned off. The residuum was extracted several times in this manner until the amount of material soluble in the acetone was very small. The acetone was then evaporated completely from the fractions and the resulting oils reserved for testing.

Vacuum Distillation.- After removing the acetone from the residuum or less soluble portion, its viscosity and specific gravity were determined. It was then distilled at 40 mm pressure, in the regular Bureau of Mines vacuum distillation unit.[4] In carrying on the distillation, as soon as a sufficient amount had collected for the first cut, (enough to make the necessary determinations), the temperature was noted and cuts were then made every 10°C. until only enough residuum for a final cut was left in the flask, when the distillation was stopped. These fractions were also reserved for testing.

A detail flow sheet of the entire process of fractionation is shown in Figure 1.

Nomenclature

The various fractions obtained by fractional solution, and by distillation have been designated as follows: The Roman numerals I, II, III, and IV refer to the cuts made in the steam distillation. Extracted fractions are denoted by the letter E, and the number following indicates the portion of that particular cut; thus II-E2 is the fraction obtained by the second extraction of steam distillation Cut II. The letter R in all cases stands for residuum. D indicates vacuum distillation, and the number following, the relative position of the fraction in the distillation; thus IV-ER-D5 is the fifth fraction obtained by the vacuum distillation of extraction residuum of Cut IV.

---

[4] - Dean and others - The Analytical Distillation of Petroleum and its Products. Bureau of Mines Bulletin 207 (1922).

TABLE II

Properties of Fractions

Sample	Viscosity 100°F.		Sp.Gr. 60°F.	A.P.I. 60°F.	Refractive Index 88°F.	Mol. Wt.	Ultimate Analysis			Ratio	Average Formulas	
	Say.	Abs.					%C	%H	%S	C/H	Empirical	Series
II-E1	61	9.4	0.934	20.0	1.5262	213	87.68	11.11	0.40	0.658	$C_{15.7}H_{24}$	$C_nH_{2n-7.4}$
II-E2	57	8.3	.917	22.8	1.5143	221	87.15	11.59	.33	.626	$C_{16.3}H_{26}$	$C_nH_{2n-6.6}$
II-E3	57	8.1	.900	25.7	1.5014	228	86.99	12.07	.32	.593	$C_{16.7}H_{28}$	$C_nH_{2n-5.4}$
II-E4	56	7.6	.883	28.8	1.4875	232	86.81	12.64	.20	.573	$C_{16.9}H_{29.5}$	$C_nH_{2n-4.3}$
II-ER	53	6.7	.844	36.2	1.4679	---	---	---	--	---	---	---
II-ER-D1	46	---	0.825	40.0	1.4528	---	---	---	--	---	---	---
II-ER-D2	43	4.2	.834	38.2	1.4563	212	85.22	13.95	.04	.509	$C_{15.2}H_{29.8}$	$C_nH_{2n-0.6}$
II-ER-D3	47	5.2	.839	37.2	1.4588	222	85.54	13.98	.04	.510	$C_{15.9}H_{31.2}$	$C_nH_{2n-0.6}$
II-ER-D4	50	6.0	.843	36.4	1.4631	235	85.46	13.78	.06	.517	$C_{16.9}H_{32.8}$	$C_nH_{2n-1.0}$
II-ER-D5	57	7.6	.848	35.4	1.4650	240	85.65	13.80	.05	.517	$C_{17.2}H_{33.7}$	$C_nH_{2n-1.1}$
II-ER-D6	63	9.0	.853	34.4	1.4658	254	85.60	13.57	.06	.526	$C_{18.2}H_{34.8}$	$C_nH_{2n-1.4}$
II-ER-DR	82	13.2	.863	32.5	1.4718	293	85.97	13.61	.09	.527	$C_{21.1}H_{40}$	$C_nH_{2n-2.2}$
III-E1	166	33.1	0.967	14.3	1.5471	233	87.37	10.58	0.54	.688	$C_{17.3}H_{25.1}$	$C_nH_{2n-9.5}$
III-E2	149	29.0	.953	17.0	1.5381	242	87.40	10.82	.54	.672	$C_{17.9}H_{26.7}$	$C_nH_{2n-9.1}$
III-E3	133	25.3	.938	19.4	1.5256	251	87.26	11.46	.46	.635	$C_{18.5}H_{29.1}$	$C_nH_{2n-7.9}$
III-E4	127	23.7	.926	21.3	1.5151	259	87.30	11.59	.40	.628	$C_{19.0}H_{30.4}$	$C_nH_{2n-7.6}$
III-ER	94	15.7	.870	31.1	1.4766	---	---	---	---	---	---	---
III-ER-D1	48	5.5	0.841	36.8	1.4601	236	85.67	13.75	---	.519	$C_{15.9}H_{32.6}$	$C_nH_{2n-1.2}$
III-ER-D2	55	7.2	.852	34.6	1.4714	---	---	---	---	---	---	---
III-ER-D3	65	9.5	.860	33.0	1.4758	249	85.22	13.73	0.18	.517	$C_{17.9}H_{33.9}$	$C_nH_{2n-1.9}$
III-ER-D4	79	12.6	.865	32.1	1.4789	271	85.75	13.54	.12	.528	$C_{19.5}H_{37}$	$C_nH_{2n-2.0}$
III-ER-D5	98	16.6	.872	30.8	1.4822	275	85.95	13.48	.15	.532	$C_{19.7}H_{37.1}$	$C_nH_{2n-2.4}$
III-ER-D6	119	20.9	.878	29.7	1.4850	295	86.51	13.66	.12	.528	$C_{21.2}H_{40.2}$	$C_nH_{2n-2.2}$
III-ER-D7	196	36.0	.882	28.9	1.4870	292	86.39	13.14	.17	.548	$C_{21.1}H_{38.5}$	$C_nH_{2n-3.7}$
III-ER-DR	287	54.3	.899	25.9	1.4966	320	86.12	12.88	.25	.558	$C_{23.2}H_{41.5}$	$C_nH_{2n-4.9}$

TABLE II (Continued)

Properties of Fractions

Sample	Viscosity 100°F.		Sp.Gr 60°F.	A.P.I. 60°F.	Refractive Index 88°F.	Mol. Wt.	Ultimate Analysis			Ratio	Average Formulas	
	Say.	Abs.					%C	%H	%S	C/H	Empirical	Series
IV-E1	918	194.4	0.996	10.6	1.5710	260	87.40	10.02	0.57	.728	$C_{19.5}H_{26.6}$	$C_nH_{2n-12.4}$
IV-E2	524	108.1	.972	14.1	1.5534	275	87.75	10.93	----	.668	$C_{20.5}H_{30.7}$	$C_nH_{2n-10.3}$
IV-E3	481	98.3	.965	15.1	1.5487	277	87.61	11.21	.54	.651	$C_{20.5}H_{31.4}$	$C_nH_{2n-9.6}$
IV-E4	396	77.8	.951	17.3	1.5371	289	87.41	11.56	.52	.630	$C_{21.3}H_{33.6}$	$C_nH_{2n-9.0}$
IV-E5	328	64.7	.934	20.2	1.5234	294*	----	----	----	--	----	----
IV-E6	255	49.2	.919	22.5	1.5103	298	86.80	12.30	----	.588	$C_{21.8}H_{37.8}$	$C_nH_{2n-6.2}$
IV-E7	250	47.8	.911	23.8	1.5004	299*	86.48	12.52	----	.568	$C_{21.7}H_{38.5}$	$C_nH_{2n-4.9}$
IV-ER	177	32.2	.879	29.5	1.4845	310*	86.33	13.42	.11	.536	$C_{22.5}H_{41.8}$	$C_nH_{2n-2.8}$
IV-ER-D1	74	11.4	.854	34.2	1.4713	319*	85.99	13.97	0.07	.512	$C_{22.2}H_{43.2}$	$C_nH_{2n-1.2}$
IV-ER-D2	104	17.6	.864	32.3	1.4765	313*	85.60	14.08	.08	.507	$C_{22.4}H_{44.2}$	$C_nH_{2n-0.6}$
IV-ER-D3	142	25.2	.871	31.0	1.4810	315	85.58	13.83	.10	.515	$C_{22.6}H_{43.8}$	$C_nH_{2n-1.4}$
IV-ER-D4	190	34.7	.880	29.3	1.4848	318	86.20	13.75	.09	.522	$C_{22.9}H_{43.7}$	$C_nH_{2n-2.1}$
IV-ER-D5	264	49.1	.885	28.4	1.4872	323	86.25	13.36	.12	.539	$C_{23.3}H_{43.3}$	$C_nH_{2n-3.3}$
IV-ER-DR	481	92.2	.906	24.7	1.4942	333*	86.42	13.64	.20	.528	$C_{24}H_{45.4}$	$C_nH_{2n-2.6}$

* Calculated.

Methods Used in the Determination of the Physical and Chemical Properties

The fractions obtained by fractional solution and vacuum distillation were studied as to their differences and similarities through determinations of their characteristic properties. The properties that were determined may be divided into two groups -- physical and chemical. The former includes viscosity, specific gravity, index of refraction and molecular weight; and the latter, carbon, hydrogen and sulphur determinations.

Experimental Data

In considering the relations between the physical and chemical properties of these samples it is convenient to consider each original cut by itself before discussing the data as a whole. Since the viscosity and specific gravity determinations are probably the most accurate, they form a good basis for the discussion of each cut.

Cut II.- In Table II, are shown the viscosities and specific gravities for the extracted and distilled portions of Cut II. It is at once evident that these fractions represent two distinct groups of oil, at least so far as the two properties in question are concerned. These variations could be caused by changes in the ratio of carbon to hydrogen due to higher members of the same series, by the presence of members of several series, and by changes in configuration. Determinations of carbon, hydrogen, molecular weight, and index of refraction should then indicate if the variation in viscosity and specific gravity can be laid to any of these causes. These properties are also given in Table II. It is at once evident from the carbon-hydrogen ratios that the extracted oils are much poorer in hydrogen and slightly richer in carbon. This is further borne out by the slightly lower apparent molecular weight of the extracted fractions, showing in conjunction with the C/H ratio, a considerable amount of unsaturation, especially when compared with the distilled fractions of the residual oil. There is, then, a decided difference in the actual composition of these two groups of oil, and also and indicated difference in constitution as evidenced by the apparent unsaturation.

This suggested difference in constitution is further strengthened by a comparison of the molecular refractions for each cut. (Table III). There is good agreement between the observed and calculated values for the distilled oils, but the observed values for the extracted oils show a decided increment over the calculated values. An increment of this kind is generally considered as being indicative of differences in constitution, which in this case is probably due to some type of unsaturation.

Cut III.- It is evident from the viscosities and specific gravities of these fractions that here as in Cut II, these are two distinct groups of oils. Again the analytical evidence points to the same indicated dissimilarity in constitution between the two groups.

TABLE III - Observed and Calculated Molecular Refraction.

Fraction	Observed M_D	Calculated M_D	Difference
II-E1	70.6	64.4	6.2
II-E2	73.3	68.0	5.3
II-E3	75.2	72.0	3.2
II-E4	76.2	73.2	3.0
II-ER-D1	69.7	67.4	0.3
II-ER-D2	73.4	72.7	0.7
II-ER-D3	77.8	76.9	0.9
II-ER-D4	79.4	78.7	0.7
II-ER-D6	83.6	82.2	1.4
II-ER-DR	95.9	95.0	0.9
III-E1	77.0	69.4	7.6
III-E2	82.1	72.6	9.5
III-E3	82.4	76.7	5.7
III-E4	85.2	79.3	5.9
III-ER-D1	77.8	76.6	2.2
III-ER-D2	----	----	---
III-ER-D3	82.3	80.6	1.7
III-ER-D4	89.6	87.8	1.9
III-ER-D5	90.4	88.4	2.0
III-ER-D6	97.2	95.4	1.8
III-ER-D7	96.0	93.4	2.6
III-ER-DR	105.0	101.8	3.2
IV-E1	86.7	76.5	10.2
IV-E2	91.6	83.4	8.2
IV-E3	92.2	84.2	8.0
IV-E4	96.1	88.5	7.6
IV-E5	----	----	---
IV-E6	97.0	93.9	3.1
IV-E7	97.4	94.9	2.5
IV-ER-D1	102.0	101.2	0.8
IV-ER-D2	103.6	102.9	0.7
IV-ER-D3	104.5	102.8	1.7
IV-ER-D4	104.5	103.5	1.0
IV-ER-D5	105.5	104.0	1.5
IV-ER-DR	107.0	108.0	1.0

Cut IV.- The same noticeable change in composition is here apparent a found in Cuts II and III, and the same indicated difference in constitution is shown by the average experimental formulas assigned to the fractions, and also by the variations in the observed and calculated values for M_D as given in Table III.

Comparison of Fractions Obtained from Salt Creek Crude with those Obtained from other Crudes.

It has already been shown that Salt Creek lubricating stock consists of two very dissimilar groups of hydrocarbon oils. Do these Salt Creek oils coincide with or resemble the lubricating fractions from typical crudes? To answer this it is necessary to present the work of certain investigators in more detail, and compare their results with those presented in this paper.

Cabin Creek Lubricating Stock.- Probably the best source of the less unsaturated inactive group is found in lubricants from Pennsylvania type crudes, of which Cabin Creek crude is very representative. The less soluble portions of Salt Creek lubricants should then resemble the lubricating oil from Cabin Creek crudes. In Figure 2 are shown viscosity-specific gravity curves comparing oils from these two sources. The data for the Cabin Creek curve has been calculated from results given by Mabery[5,6] and every effort has been made to avoid errors in the conversion of the original viscosity and specific gravity figures to the ones plotted.

The composite viscosity-gravity curve representing the less soluble portions of Salt Creek lubricating stock is shown by the heavy line. At a viscosity of 16 Cp. or below it is practically a continuation of the lower portion of the Cabin Creek curves. Above 16 Cp. it coincides very closely with the average of these two curves, indicating that the fractions obtained from Salt Creek crude are similar to those obtained from the Cabin Creek oil.

Sour Lake Lubricating Stock.- Another crude that was studied in considerable detail by Mabery[7] was Sour Lake petroleum. This, in direct contract to Pennsylvania type oil, should consist largely of the so-called "unsaturated" high carbon-hydrogen ratio group of lubricants as described by several writers. Since the solid asphaltic material was not removed before fractionation as was the paraffin from the Appalachian oil, there is the possibility of some asphalt being dissolved in the fractions; but the results should, nevertheless, be typical for that type of lubricant. If the viscosities and specific gravities, after conversion to standard units, are plotted, the curve is of the type shown by the dash lines in Figure 2. The heavy line drawn through the average points as obtained for the extracted fractions of each cut represents the general trend of the soluble portions of Salt Creek lubricants. These two curves are very

---

[5] - Mabery, C. F., The Lubricant and Asphaltic Hydrocarbons in Petroleum. J. Ind. Eng. Chem. Vol. 15, 1923. p. 1233.

[6] - Mabery, C. F., The Composition of Mid-Continent Petroleum. J. Ind. Eng. Chem. Vol. 18, 1926, p. 814.

[7] - Mabery, C. F., Work cited.

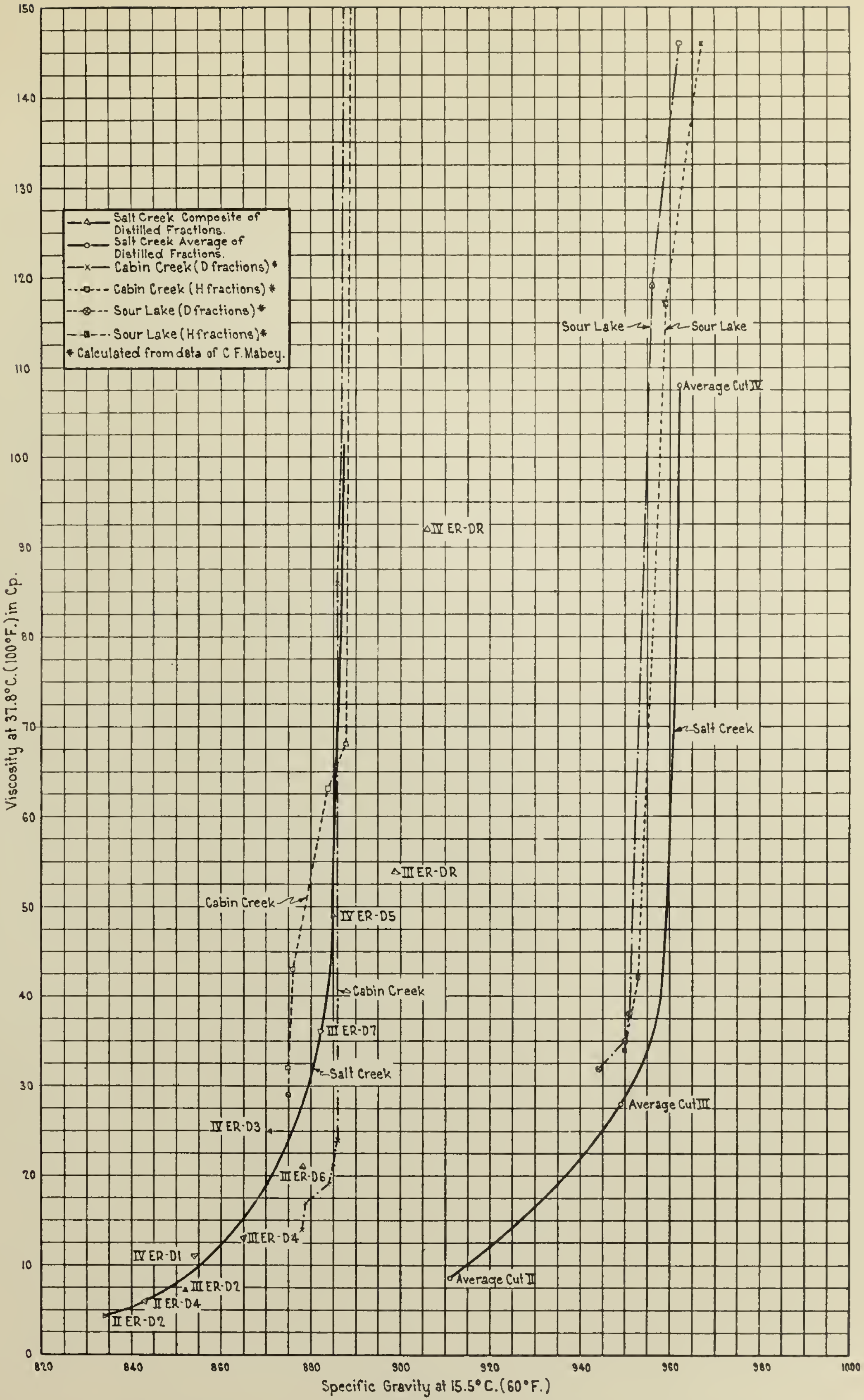


FIGURE 2

Viscosity-Specific Gravity Curves for Fractions from Salt Creek, Cabin Creek and Sour Lake Crudes.

close and practically parallel, the Salt Creek curve in its lower portion being almost an extension of the Sour Lake viscosity-gravity ratios.

Summary of Results, and Conclusions

If the evidence of the literature can be trusted--that viscosity and specific gravity are functions of the composition and constitution of the oil--then the soluble Salt Creek fractions are members of the same so-called "saturated" group of hydrocarbons to which Pennsylvania lubricants belong, as typified by the lubricant fractions of Cabin Creek petroleum.

If, for the unsaturated oils, as in the case of the "saturated" group of oils, viscosity and specific gravity can be construed to indicate difference and similarity in constituion, then the Sour Lake and Salt Creek oils have portions in their lubricating stock which may be classed in the same group with each other.

The data given by the tabulation of these properties show that there are present in the lubricating stock of Salt Creek petroleum two distinct groups of oils; one relatively insoluble in acetone, having low viscosity-gravity ratios, low carbon-hydrogen ratios, and relatively low unsaturation; the other group showing, in contrast, good solubility in acetone, high viscosity-gravity and carbon-hydrogen ratios, and considerable apparent unsaturation.

The less soluble oils present in lubricants from Salt Creek crude have been shown to be of the same class as lubricants from Cabin Creek petroleum, which consist largely of the low carbon-hydrogen ratio type of oil.

The extracted or more soluble portions of Salt Creek lubricating stock is very similar to the lubricating portion of Sour Lake crude oil.

Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un32mo
cop. 2

ial 2838
November, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

B

THE LIBRARY OF THE
JUL 23
UNIVERSITY OF ILLINOIS

SAFETY MEASURES SAVE LIVES IN COLORADO EXPLOSION

By E. H. Denny[1]

Introduction

On May 27, 1927, a coal-dust explosion occurred at the Delagua No. 3 mine of the Victor American Fuel Company, Delagua, Colorado, resulting in the loss of seven lives and in considerable damage to the main slope and to several overcasts. The explosion did not extend into the mine workings where 125 additional men were employed but escaped uninjured. It is believed that the saving of these 125 men and the avoidance of large property loss were due in a large measure to rock-dusting and other safety measures taken by the coal company management. A number of features connected with the explosion and mine safety practice seem worth bringing to the attention of the mining public, and grateful acknowledgment is made to the Victor American Fuel Company for its aid in assembling the data herein contained.

Mining Conditions

The Delagua No. 3 mine is opened by two parallel slopes having an average grade of between 4 and 5 per cent. One of these is used for rope haulage and carries part of the intake air; the other carries the return air from the mine. At the time of the explosion mining operations were confined to four level entries, namely, the third, fourth and fifth north entries, turned to the north of the slope, and the 6th north off the 5th north entry. The mine is an old one with the nearest work to the slope about 2600 feet distant; most of the active workings, however, were over twice this distance from the slope. Rooms between the level entries are driven to intersect and the workings connect with No. 2 mine through caved ground. Auxiliary openings to the surface off the 5th and 6th north entries serve also as air intakes. The mine is said to have encountered no explosive gas and is rated as non-gassy; it is ventilated by an exhaust fan located at the mouth of the return air slope giving an air circulation of approximately 64,000 cubic feet per minute. The air is well split by overcasts and auxiliary surface intakes. The mine produces about 1,000 tons of high-grade, high-volatile, bituminous coal daily. The coal is undercut by machine and shot with permissible explosive. Direct current, 250-volt power for pumps, haulage motors, and cutting machines was taken into the mine through the main slope by wires suspended from the ribs and roof. The slope was electrically lighted.

---

[1] District Engineer, Bureau of Mines, Department of Commerce.

Story of the Explosion

The explosion was initiated by an electric arc in a cloud of coal dust when a runaway loaded trip became derailed and pulled down power and light wires. The coupling on the fourth car of a twenty-car trip broke and sixteen cars ran down the slope for 125 to 150 feet before the drag on the rear car derailed the trip, piling up the cars in a manhole and on the slope. Evidences of arcing were discovered later on the metal body of one car and on the irons of two cars with wooden bodies. The cars had been loaded with coal containing much dry, fine, coal dust. The explosion came up the slope with considerable violence for 1200 feet to the slope mouth, caved the slope portal, and set fire to a surface building. It traveled down the slope for about 300 feet and into the third and fourth north entries for about 2,000 and 400 feet, respectively; all evidence of force and violence quickly disappeared beyond these points. Overcasts at the third and fourth north entries were blown out, destroying the usual course of ventilation; however, these entries probably secured a little ventilation over the gobbed territory from No. 2 mine and the fifth and sixth entries secured a good volume of air from the surface openings. The fan was undamaged by the explosion and was quickly restarted, enabling the "afterdamp" from the explosion to be carried out of the mine in about thirty minutes.

The rope runner on the trip and a track man on the slope were killed instantly. Two motormen and two nippers from the fourth north entry evidently hurried out a distance of 3500 feet to the main slope. About 1,000 feet from the main slope they found an injured man and apparently carried him a considerable distance; this injured man was found unconscious by a rescue party and died later. In proceeding to the slope the four men inhaled much afterdamp,- probably a greater amount because of their exertions, - collapsed and died a short distance from the main slope.

Eighteen men with a mine foreman and assistant foremen were in the third north entry at the time of the explosion. The two officials felt a concussion which they believed at first to be due to a fall of rock; but on starting out they found evidence of an explosion. They then returned to their men and placed them behind a canvas stopping in one of the rooms where they remained until released by a rescue party.

Thirty-one men were in the fourth north entry at the time of the explosion. The fate of four of these who tried to make their way out and of the injured man has already been described. Two others later made their way out of this entry unassisted while the remainder, including a driver boss, after one or more attempts to penetrate bad air, remained near their places until a state mine inspector reached them about three hours after the explosion.

About 80 men including a mine foreman and an assistant were working in the fifth and sixth north entries at the time of the explosion. The foreman first knew of the trouble when he found that the power had been off for thirty minutes;

he then found that the telephone to the surface was not working and that the slope was caved. He and his assistant then told the men that because of a cave in the slope there would be no more work that day and ordered the men to go out by the auxiliary openings in the fifth and sixth north entries.

Of interest also is the fact that the explosion shook checks off the board in the check house, making it difficult during rescue work to determine the exact number of men in the mine.

Mine Recovery Work

A representative of the State Inspection Department and local mine officials quickly organized rescue parties and had penetrated the slope for some distance by the time the men who escaped unassisted from the third and fourth north entries were making their way out. Other state inspectors, a rescue car crew with gas masks and officials from the Colorado Fuel and Iron Company, other mining company officials, and a U. S. Bureau of Mines car with men, oxygen breathing apparatus and gas masks came to the scene quickly so that within two hours of the explosion recovery operations were well under way. A carbon monoxide detector and gas masks were used to a limited extent on recovery work, the air clearing very rapidly. Four and three quarter hours after the explosion all miners were accounted for and out of the mine.

Safety Measures and Conditions Having a Bearing on Explosion Limitation

The Victor American Fuel Company was one of the first mining companies in the United States to start generalized rock-dusting and the use of rock-dust barriers. As early as 1911 natural adobe dust was taken into the mine and scattered on timbers and on roadways. Board shelves carrying adobe dust were also placed on timbers and fastened to ribs at convenient points. This use of dust and barriers was gradually extended. Several years ago a pulverizing plant was established at Delagua and the Company from time to time has continued the application of pulverized adobe dust by machine and hand, such application being made principally to haulage entries. The back entries have been given protection by shelves of adobe dust; there is also considerable natural roof rock or shale sloughing, thus adding to the incombustible matter on the floor; and in places considerable standing water is found in back entries. Samples of mine dust taken after the explosion from the ribs, timbers, and roadways of slopes and entries showed an average incombustible content both in road and in rib and timber samples approximating the minimum recommended by the U. S. Bureau of Mines, namely 55 per cent, and in many instances the incombustible was over 55 per cent. It was noticeable that the samples containing the largest percentage of fine (under 200 mesh) dust had also the highest incombustible content, thus showing the effect of the pulverized adobe dust distribution. Dust samples from an unrock-dusted room gave incombustible content of the natural mine dust in this room as rib dust 27.1 per cent, road dust 34.5 per cent. This analysis contrasted with high incombustible content in rock-dusted regions also showed the large amount of additional incombustible which had been added to the mine dust in rock-dusted portions of the mine.

Car spillage had made it difficult to keep haulageways clean and sprinkling with water was practiced on the slope and on part of the 6th north entry. On the morning of the explosion water taps had been open on the slope between the fourth and fifth north entries, and this probably aided in preventing propagation down the slope. No water was in use on machine cutter bars nor were loads sprinkled.

The explosive character of the coal dusts of the Trinidad district has been well demonstrated by the explosions which have occurred there in mines classified both as gassy and non-gassy. Ten explosions resulting in the death of 10 or more men each have occurred in the Trinidad field during the past 21 years. These explosions have generally been widespread and very destructive. In 1910 an explosion at time of fire in the Delagua mine killed 79 men. The Delagua No. 3 mine, as stated before, is rated as non-gassy, and even after the explosion had deranged ventilation no methane could be found with a safety lamp and the maximum amount of methane carried by any return or found in any working place was, by chemical analysis, 5/100 of one per cent. The explosion occurred on the main intake within 1,200 feet of the surface and far from working faces; it is believed that the fine coal dust from the wrecked trip supplemented possibly by some coal dust accumulation on slope, floor and timbers, gave the necessary fuel for the limited explosion which resulted; and it seems practically certain that the general distribution of adobe dust, together with the shelf barriers, plus a little aid from water on the slope, definitely checked the explosion propagation and prevented a general disaster The rock-dusting done by the company management, the auxiliary mine exits provided, and the fortunate blowing out of the overcasts which prevented the afterdamp from reaching the men in the third and fourth north entries resulted in the saving of the lives of 125 of the 132 men in the mine.

The ignition of coal dust stirred up by a wrecked trip fortunately does not always result in a general explosion. An Alabama and a recent Pennsylvania explosion are two samples of localized explosions started by an electrical arc in a cloud of dust from a wrecked trip. In the first case destruction of life and property was largely confined to the main parting, an effective watering system aiding materially in preventing widespread propagation; and in the second, the explosion traveled over 6,000 feet of haulage road practically to the surface but did not extend inby the trip wreck to parts of the mine where many men were working. On the other hand, a New Mexico explosion which was initiated on the main road about 1,600 feet from the surface is an example of an explosion starting on an intake and traveling throughout the mine.

In the Pennsylvania explosion 36 cars broke away from a trip on an incline and 16 of them ran to the bottom of the incline where the wheel of one of the overturned and wrecked cars came in contact with a power cable. The mine had three drifts and three shafts to the surface, several of these exits being in comparative proximity to the working faces. An extensive system of mine telephones was not disturbed by the explosion and it was possible from the surface to direct the men in the various sections of the mine to safe exits so that they would not have to come through the poisonous gases from the explosion. Thus approximately 300 men in the mine were saved, the only lives lost being those of four haulage men. Barricades were used in several cases. All recovery work was completed in about four hours. The coal in this particular mine in Pennsylvania is a low volatile coal and while low volatile coals are less explosive than high volatile coals, yet disastrous explosions have occurred in mines producing low volatile coal.

Safety Lessons

1. The use of rock dust supplemented by water in the Delagua No. 3 mine is believed to be in a large measure responsible for the saving of 125 lives and for the avoidance of great property damage.

2. At the Delagua and Pennsylvania explosions, auxiliary exits and openings to the mine afforded opportunity for the quick escape of men after an explosion, as well as giving an opportunity for natural air circulation from the surface.

3. In the average mine, rock-dusting is likely not to be kept near enough to the faces and is likely to be insufficient at partings.

4. A trip derailment on a slope of very moderate pitch is likely to raise a cloud of coal dust of sufficient density to be ignited by an arc and cause an explosion; the ordinary drag may not derail the trip until it has gone backward one hundred feet or more, the momentum gained in such distance being sufficient to cause violent impact and produce heavy dust cloud where the cars are wrecked.

5. Wiring on a slope used for haulage is a hazard and should accordingly be protected by channeling or by burying in order to avoid dangerous arcing in case of a trip wreck.

6. The recessing of slope timbers in the rib makes them less likely to be pulled down by a trip wreck, consequently the accumulated dust on the timbers is less apt to be disturbed by a wreck.

7. Frequently a miner can save his life after an explosion by simply remaining at or near his working place. But unless he takes some measures toward keeping the poisonous gases formed by the explosion from coming in on him he is likely to be killed by these gases. Training of officials and miners at individual mines in the erection and use of barricades following explosions is needed, and all miners should be familiar with U. S. Bureau of Mines Miners Circular 25 on "Erection of Barricades During Mine Fires or After Explosions."

8. Gas masks affording protection against carbon monoxide proved of some service in the recovery work following the Delagua explosion.

9. The thorough wetting of the tops of loaded trips and wetting of coal piles at the face should largely remove the hazard of coal dust ignition following a wreck if haulageways are adequately rock-dusted. In some instances the fine coal dust along haulage tracks is kept watered even when the ribs, roof and floor are rock-dusted and experimental work has demonstrated that this is decidedly good policy.

10. The check house as well as all other surface structures should, if feasible, be located well to the side of a direct line from any opening to a coal mine. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un 32 mo
cop. 2

Serial No. 2839.
November, 1927.

THE LIBRARY OF THE
JUL 2 3 195
UNIVERSITY OF ILLINOIS

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE--BUREAU OF MINES.

DEVELOPMENT OF SOME FUNDAMENTALS IN THE FERRIC SULPHATE -- SULPHURIC ACID PROCESS

By Frank S. Wartman and Harmon E. Keyes[1]

The Ferric Sulphate - Sulphuric Acid Process, developed by the staff of the Bureau of Mines, is a method of making mixed solutions of ferric sulphate and sulphuric acid suitable in quantity and composition for leaching certain types of low-grade oxide - sulphide copper ores.

Fundamentally, the process consists of bubbling gas mixtures such as are obtained from a sulphide roaster and which contain sulphur dioxide and oxygen in addition to various other gases, through a solution of ferrous sulphate such as is obtained when copper is precipitated from a sulphate solution by replacement with metallic iron. When the proportion of sulphur dioxide to oxygen is not too great and the gas mixture is not passed through the solution too rapidly, the iron in the solution and the sulphur dioxide are simultaneously oxidized according to the reaction:

$$2\ FeSO_4 + SO_2 + O_2 = Fe_2\ (SO_4)_3.$$

Further passage of the gases through the solution, after the iron present therein has been nearly completely oxidized, results in a steady state, wherein ferric iron is being reduced by SO_2 and re-oxidized simultaneously with oxidation of sulphur dioxide, so that the net result is formation of acid according to the equation:

$$SO_2 + H_2O + 1/2\ O_2 = H_2SO_4$$

The data and observations accumulated as a result of the small-scale laboratory investigations of several men have been compiled and collated by Ralston[2]. The early work of the Southwest Experiment Station was briefly covered in a Bureau of Mines publication[3]. The results of later tests with a small pilot plant[4] and with a larger scale plant[5] operated on the property of the Pinto Valley near Miami, Ariz., have been reported.

---

[1] Assistant Metallurgist, and Associate Metallurgist (resigned), respectively, Southwest Experiment Station, Bureau of Mines.

[2] Ralston, O. C., and Maier, C. G., The Ferric Sulphate -- Sulphuric Acid Process: Bull. 260, Bureau of Mines.

The various fundamental factors accountable in the process have been well covered in the report by Ralston. However, since some of the early work was done with types of apparatus very unlike that adopted for large-scale work, and inasmuch as the type of apparatus used has a marked effect on the results obtained, a repetition of some previous experiments with apparatus and procedure similar to that adopted for large-scale practice was thought desirable. In addition, a considerable amount of work has been done on the technique of making contact between the gases and liquids entering into the reaction. The results of these various investigations are reported herein.

Laboratory investigation has shown that of the two stages, iron oxidation and acid making, the former requires much more careful control and that any set of conditions satisfactory for oxidation will likewise be suitable for acid production. The large-scale, continuous cycle work using impure solutions and roaster gases has shown that the two steps become more or less simultaneous. During the oxidation stage, 20 to 40 per cent of the sulphur dioxide added goes to form free acid. Therefore, since the oxidation step requires more careful regulation and since the two stages take place more or less concurrently, the oxidation stage has received more consideration in this work.

I. What size of bubble should give the most efficient aeration?

The term "aeration" has been applied to that portion of the process in which the roaster gases are brought into contact with the iron-bearing solutions. During the early development of the process there was some argument as to whether small or large bubbles would give the most efficient result. Maier[6] conducted an investigation to determine the effect of varying the bubble size upon the efficiency of the process. Jennings[7] made a similar study in which he used gas mixtures of varying composition. In Table 1 are given values of the sulphur dioxide efficiency (per cent of total sulphur dioxide gas admitted to the reaction tube which was utilized by the oxidation reaction) for various diameters of bubbles and concentrations of sulphur dioxide in the gas mixture. The gas mixture for this series contained 18 to 20.5 per cent of oxygen.

---

[3] Leaver, E. S., and Thurston, R. V., Reports of Investigations, Bureau of Mines, Serial No. 2536, Dec. 1, 1923.

[4] Oldright, G. L., Keyes, H. E., and Wartman, F. S., Production of Ferric Sulphate and Sulphuric Acid from Roaster Gas: A.I.M.M.E. Trans., Vol. LXXIII, p. 84.

[5] Keyes, H. E., and Oldright, G. L., Application of the Ferric Sulphate - Sulphuric Acid Process: unpub. report of Bureau of Mines.

[6] Ibid 2.

[7] Jennings, W. A., The Effect of Bubble Size on the Optimum Sulphur Dioxide - Air Ratio in the Ferric Sulphate - Sulphuric Acid Process: Thesis, University of Arizona, 1925.

Table 1.

Sulphur dioxide efficiencies for various bubble sizes used in combination with varying SO_2 in reaction gas mixture.

Per cent gas admitted to reaction tube	Per cent sulphur dioxide efficiency			
	1 mm. dia. bubbles	2 mm. dia. bubbles	3 mm. dia. bubbles	5 mm. dia. bubbles
0.75	23	93	99	56
1	30	98	100	57
2	66	90	80	75
3	85	61	46	27
4	76	43	25	13
5	60	29	13	2

On the basis of these data we may conclude that with these conditions and with this type of apparatus there exists for each ratio of sulphur dioxide to oxygen a certain size of bubble which will produce the most efficient result. Experiments with gas mixtures containing a lower oxygen percentage showed a less definite maximum efficiency for a specific bubble size and also showed that as the oxygen content of the gas was lowered the point of maximum efficiency came at a lower sulphur dioxide percentage.

Jennings was not able to make porous media which would give a definite size of bubble and at the same time pass large volumes. His apparatus held only 60 c.c. of solution and about 20 c.c. of gas were passed through per minute. Inasmuch as the column height was 60 cm., it will be seen that the ratio $\frac{\text{bubble diameter}}{\text{diameter of aerator}}$ was enormously larger than for the large scale tests. How large an effect this changed ratio had on the results obtained is not known.

Large-scale operation has definitely proved that small bubbles are more desirable than large bubbles, but since it has been impossible as yet to construct a commercially satisfactory aerator which would give uniformly-sized bubbles of a definite and predetermined diameter, the more particular details of the above conclusions have not been confirmed by the results of larger scale operation.

II. What should be the temperature of the iron sulphate solution during the aeration?

In this series of experiments a vertical glass tube about 5 feet high and 1-1/4 inches in diameter, with the lower end closed by a rubber stopper, served as a container for the ferrous sulphate solution to be aerated. The gas mixture was divided into small bubbles by forcing it through a piece of thick, closely-woven woolen cloth tied over the enlarged upper end of a glass tube. This tube, by penetrating the stopper at the lower end of the large tube, served to introduce the gas mixture into the solution. Means were provided for maintaining the temperature of the solution in the large tube at any value between 10 and 80°C. Each experiment started with a solution containing 5 grams of divalent iron per liter. The amount of air admitted was kept constant at 550 c.c. per minute, and the amount of pure sulphur dioxide mixed with the ingoing air was varied until the maximum amount which could be completely used at a particular temperature was found. In Table 2 are shown the maximum per cents of sulphur dioxide which could be so mixed with the ingoing air.

Table 2

Showing relation between temperature of solution and maximum per cent of sulphur dioxide allowable in ingoing gas.

Temperature of $FeSO_4$ solution, °C.	Maximum allowable per cent SO_2	Ratio $\frac{\text{Per cent } O_2}{\text{Per cent } SO_2}$
10	3.5	5.5
15	5.2	3.6
20	6.8	2.7
30	8.3	2.2
50	11.3	1.57
70	14.1	1.22
80	14.7	1.16

It will be seen that within the limits of temperature studied, increased temperature favors the progress of the iron oxidation reaction.

III. What should be the proportion of sulphur dioxide to oxygen in the roaster gas used for aeration?

Inasmuch as the ferric sulphate process was developed with the idea in mind of using waste roaster gases, it was desirable to know what effect would be produced if the aeration were conducted with gases containing less oxygen than the synthetic mixtures previously used in the laboratory which were made from air and pure sulphur dioxide. In an apparatus similar to that described in the previous section, Cha[8] aerated solutions with mixtures of air, nitrogen, and sulphur dioxide.

---

[8] Cha, L. A., The Effects of Initial Acidity and Oxygen-Deficient Air on the Sulphur Dioxide Efficiency in the Ferric Sulphate - Sulphuric Acid Leaching Process: Thesis, University of Arizona, 1926.

The percentage of sulphur dioxide was kept constant at 4 in all gas mixtures, and the temperature of the solution being aerated was kept at 40°C. The initial solution contained 5 grams of divalent iron per liter and the initial acidity was varied as shown in Table 3, which gives the per cent of sulphur dioxide utilized under the conditions shown.

Table 3

Effect of changes in ratio $\frac{O_2}{SO_2}$ and initial acidity upon SO_2 efficiency.

Ratio $\frac{\% O_2}{\% SO_2} = \frac{\% O_2}{4.0\%}$	Initial acidity of the solution		
	Neutral	9.5 gm. H_2SO_4 per liter	20 gm. H_2SO_4 per liter
5	93	93	71
4	92.5	91	69
3	90	87	65
2	87	74	56
1	77	32	9
0.5	22	9	3

Another series of runs with initially neutral solutions and with other conditions differing appreciably only in that carbon dioxide was used as a diluent to reduce the partial pressure of oxygen in the gas mixture, gave data which substantiate that given in the foregoing table. The table is self-explanatory; it should be held in mind that here as well as in the tables before given, only the relative values of sulphur dioxide efficiency obtained on small-scale work when applying the conclusions thereby obtained to large-scale apparatus, are signigicant. Absolute sulphur dioxide efficiency is so much influenced by various mechanical factors that actual values of sulphur dioxide efficiencies for small and large apparatus operating under similar conditions are not the same. The actual efficiency of the large-scale apparatus is invariably lower under comparable conditions of capacity. Conversely, if the same efficiency of sulphur dioxide is to be maintained the relative capacity of larger aerators is lower.

IV. Studies dealing with the coalescence of bubbles.

The most important single element of the process is the aeration - the forming of contact surface between the gases and solutions entering into the reaction. It has been shown above that certain conditions demand that the gas be divided into bubbles of a certain size, and that in general small bubbles are more desirable than large bubbles.

During operation of large-scale aerators it has been observed that bubbles from the same bubble-making device were much larger by the time they had risen to the surface of some solutions than they were at the tops of other solutions. Since the control of bubble size and especially the prevention of very large bubbles is of importance in the working of the process, a laboratory investigation of the behavior of bubbles rising through various types of solutions was initiated.

A small glass aeration cell with plane parallel sides similar to Maier's apparatus was made, so that photographs of the bubbles suspended in the solution could be made without the distortion of image produced by the curved surfaces of the glass tubes hitherto used as laboratory-size aerators. The bubble-producing device was a gang of glass capillaries of such bore that the diameter of the bubbles when first formed in water was about 1 millimeter.

Samples of various pilot-plant solutions and synthetic solutions from the laboratory were treated in this apparatus. Photographs were taken of the bubbles just after they had formed in the solution and again after they had risen some distance through the solution. These photographs show beyond doubt that the composition of the solution has no measurable effect on the size of the bubble when first formed, and that as they rise through the solution they coalesce into larger bubbles much more rapidly in some solutions than in others. When this fact had been established, the aeration tube was tilted so that the tendency to coalescence would be magnified by the bumping and rubbing of the bubbles along the upper side, and a detailed study of the factors influencing the coalescence was made.

The formation of an interface between a gas and a liquid requires the expenditure of energy in proportion to the area of the surface produced, and when the gas and liquid phases are left undisturbed they will so adjust themselves that the energy tied up in the interface will be a minimum; that is the area of the interface will be as small as it can be made by the spontaneous action of the system concerned. When a unit volume of a gas in the form of small bubbles is suspended in a liquid, the total area of the interface will be inversely proportioned to the average bubble diameter. When left to themselves the bubbles will coalesce into large bubbles so as to lessen the interfacial energy of the system. This is the fundamental cause of the coalescence of bubbles. When two bubbles of equal diameter coalesce to form one large bubble, the surface energy of the latter is about 20 per cent less than the sum of the surface energies of the two original bubbles. It is to be noted that the actual quantity of energy involved decreases rapidly as the size of the bubble increases. The 20 per cent energy decrease for a liter of gas in the form of 1 mm. bubbles coalescing by pairs as indicated above would amount to 12,000 dyne-centimeters; the energy decrease for a liter of gas in the form of bubbles 5 millimeters in diameter coalescing in the same manner is only 2,400 dyne-centimeters. Thus, the smaller the bubble, the greater the tendency toward coalescence. A corollary would be that there is a limit to the size of bubble which will be produced by coalescence, because as the size increases, the force driving it to further coalescence becomes less and less. Actual practice bears out this statement since any appreciable proportion of bubbles as large as a centimeter is not often found, and its existence is regarded as indicating very abnormal conditions in the aeration cell. It has been observed also that the smaller bubbles coalesce first.

There has been much work done on coalescence, especially by colloid chemists, and causes for coalescence other than that given above have been considered. The influence of surface energy upon coalescence is merely offered as a simple explanation which fits the observed experimental facts.

In order that two bubbles may coalesce, they must first touch each other; then the film of liquid which separates the two must be ruptured. These simple facts are the bases for two different methods for the control of coalescence. By mechanical means we may control the number of contacts or collisions between bubbles; by physical and chemical means we may change the properties of the film which envelops the gas and makes the bubble.

There are a great many substances which, when added to the aerated solution, affect the amount of coalescence taking place through some action on the bubble film. Inorganic salts and alkalies when present to the extent of a few per cent by weight retard coalescence. Pine oil, glue, gelatin, alpha-naphalamine, and thiocarbanalid, when added to the solution in amounts as small as 50 parts per million by weight, diminish the degree of coalescence to a marked extent. Glue and gelatin are weakest in effect, but last for a longer time. Phenol, eucalyptus oil, castor oil, glycerine, pyridine, potassium xanthate, butyric acid, stearic acid, and egg albumin have no effect when used in concentrations less than 100 parts per million. Sulphuric acid and sulphurous acid have a slightly accelerating effect on coalescenc Carbonic acid is without effect. Any kind of soap when present to the extent of only two or three parts per million will induce marked coalescence. Sharp, dense, siliceous particles suspended in the aerated solution in the proportion of 15 or 20 grams per liter will accelerate coalescence markedly. Soft, flocculent particles do not have as great effect. It was shown by surface tension measurements that there was no correlation between static or dynamic surface tension and coalescence. With the solutions under discussion, when coalescence is prevented the aeration is accompanied by an abundant froth. Conversely, when the bubbles coalesce the froth disappears. Many investigators have laid stress on the connection between froth production and surface tension lowering. However, these tests have shown that many substances prevent coalescence and induce frothing, which have no appreciable effect in lowering the static or dynamic surface tension of the solution.

This summarizes our present knowledge of the control of coalescence through varying the properties of the liquid film of the bubble. There are two chief measures available for mechanical control by prevention of bubble collisions.

In the first place, the number of collisions between bubbles will be lessened if the bubbles are of the same size. Large bubbles rise faster than small bubbles and if the bubble-producing device gives bubbles of various sizes, the different rates at which they rise through the solution will offer many opportunities for collisions and coalescences.

In the second place, a proper proportioning of gas volume to solution volume is necessary. The solution in the aerator may be considered in the light of an "emulsion" in which the gas bubbles are the dispersed phase and the solution is the continuous phase. Since salt solutions do not form very elastic films, the layers of solution between bubbles must be fairly thick if the bubbles are to remain dispersed. In the region just above the porous medium where the bubbles are formed it is especially necessary to make sure that the liquid supply is sufficient to keep the bubbles separated after they are formed.

V. What relation exists between the rate of absorption of oxygen by a particular solution and the ease with which the solution may be treated by the Ferric Sulphate Process?

During the earlier laboratory work on the process, a vertical glass tube about 5 feet long was used as an aeration vat. Pure sulphur dioxide was run in through a jet in the bottom of the tube at the rate of 80 cubic centimeters per minute and pure air was admitted separately at the rate of 800 cubic centimeters per minute. Repeated experiments showed that if the air were admitted in the form of small bubbles, the sulphur dioxide would be used and the reactions previously given would take place; if the air were admitted in large bubbles, the sulphur dioxide would pass off at the top of the tube and the iron would not be oxidized. In each case the same amounts of air and sulphur dioxide were admitted into a solution of the same composition and volume, and held in the same container. The only factor changed was the area of the interface between air and solution. This phenomenon may be explained by assuming either that the reaction is a case of surface catalysis, or that the rate of solution of oxygen gas, which is of course proportional to the area of the interface, other things being equal, is the governing factor. Experiment has shown that when iron sulphate solution is trickled down an absorption tower filled with crushed quartz, up through which mixtures of air and sulphur dioxide are passing, very little oxidation occurs, even though the gas liquid interface is of the same magnitude as that in the liter capacity aerating tubes. It would, therefore, seem that one of the factors important in limiting the rate of the reaction as it is usually carried out is the rate of absorption of oxygen by the solution.

The natural conclusion from these results is that any coefficient which represented the rate of solution of oxygen in a particular iron solution would likewise represent the ease with which the solution could be treated by the ferric sulphate process.

To test this conclusion experimentally, an apparatus for estimating the rate of absorption of oxygen by a particular solution was constructed as follows: A piece of glass tubing about an inch and a quarter in diameter and five feet long was drawn down at one end to a diameter of one-half inch and a piece of a burette having a holding capacity of 12 c.c. was attached firmly with a short length of heavy rubber tubing. A stopper carrying a glass stopcock was inserted in each open end of the combined tube which had an internal volume of about 1 liter. A small leveling bulb was connected to the stopcock at the large end by means of a 5-foot length of tubing.

With this apparatus, absorption rate determinations were made in this manner: The stopcock at the leveling bulb end was closed and the interior of the tube evacuated by attaching the burette and stopcock to a suction pump. Then the leveling bulb was immersed in the solution to be tested and this solution allowed to flow into the tube until it was entirely full. The solution had been previously boiled and cooled to room temperature in a tightly stoppered bottle. After the tube had been filled with liquid, it was disconnected from the suction and while in a vertical position with the burette end up, 10 c.c. of pure oxygen were run in and the stopcock at the burette end was again closed. The stopcock at the large end was also closed and the tube was turned end-for-end so that the large end was uppermost. The oxygen which had been in the burette end formed into a large bubble which rose to the upper end of the tube. As soon as the bubble had reached the top, the tube was turned to its former position. Two more such inversions were made and then the volume of gas remaining was read off after it had been brought to atmospheric pressure by means of the leveling bulb. Ten such groups of inversions and readings were made on the same sample. The oxygen absorption coefficient was determined by multiplying by 100 the difference between the volume of oxygen absorbed in the first five groups and that absorbed in the second five groups. There is no particular theoretical significance to this procedure. It is merely the method which was found to give the most concordant results with the minimum of apparatus and effort. It is advisable to add to the solution just before it is drawn into the absorption tube about 1 c.c. of a 1/2 per cent castile soap solution in order to prevent bubbles at the meniscus in the burette. Bubbles are undesirable because they make difficult the reading of gas volumes and also because the thin walls of the bubbles standing in contact with the oxygen gas take up a large quantity and give erratic absorption values. Values as determined for some solutions are given in Table 4.

Table 4

Oxygen absorption coefficients for some solutions.

No.	Composition of solution	Absorption coefficient
1	Distilled water	100
2	$CuSO_4$, 40 gm. Cu per liter	45
3	do 30 do	54
4	do 20 do	69
5	Na_2SO_4, 100 gm. per liter	69
6	NaCl, 100 gm. per liter	48
7	Ferrous discard solution from sponge iron, Fe++, 42 gm. per liter	43
8	Same as above diluted to Fe++, 30 gm. per liter	50
9	do 20 do	62
10	do 10 do	70
11	do 5 do	86
12	$FeSO_4$ pure, 5 gm. H_2SO_4, 10 gm. Fe++ per liter	70
13	Pregnant solution from zinc leaching plant, Zn, 48.7; Cu, 2.1; H_2SO_4, 33; Fe, 16; S, 61 gm. per liter	13
14	Pregnant solution from copper leaching plant, Cu, 21.5; H_2SO_4, 20.9; Fe, 27 gm. per liter	32

Past experience has shown that solutions 10, 11, and 12 can be easily treated. Experiments have proved that solutions 13 and 14 can not be treated successfully without very careful manipulation and greatly reduced capacity, and that solution 8 gives a smaller capacity than 10 and 11. These facts are reflected in the oxygen absorption coefficient, which is large for easily-treated solutions and small for difficult ones.

It is evident that some knowledge of the composition of the solution is necessary. On the face of the coefficients given above, distilled water would be the most suitable of all and this is of course not attainable. Because of the fundamental nature of the reactions involved a certain concentration of iron sulphate is essential. Other salts should be kept to a minimum, and for maximum capacity the iron concentration should not exceed 5 grams per liter.

It must be said that the rate of solution of oxygen is not the only factor limiting the rate of the reaction. Maier showed that it is possible to increase the partial pressure of oxygen to a point where the solution is saturated. The increase of rate with increase in temperature likewise indicates the presence of other factors. Yet, under the conditions met in large-scale work, it has been very definitely shown that, from the standpoint of the two-film theory of gas absorption, the type of apparatus best adapted to produce rapid solution of oxygen gas in the aerated liquid is most satisfactory, and those solutions which absorb oxygen most rapidly are most easily treated. We must, therefore, conclude that although rate of oxygen absorption is not the only variable limiting the reaction rate, yet it is an important one.

SUMMARY

A further study of the iron oxidation step of the Ferric Sulphate - Sulphuric Acid process reveals the following:

For each particular set of conditions in aeration there is a size of bubble which will give the most efficient result. Small bubbles are in general more desirable than large bubbles.

Within the limits 10 to 80°C., the higher the temperature, the more rapidly may the iron be oxidized.

For efficient operation in pure solutions at a temperature of 40°C., there should be at least three times as much oxygen as sulphur dioxide in the ingoing gas. The initial solution if completely reduced should not contain over 10 grams per liter of sulphuric acid.

There is no apparent relation between the value of static surface tension of the solution and the degree of bubble coalescence.

Coalescence of bubbles during the aeration process may be controlled by mechanical or physical means. Mechanical means include the even sizing of bubbles and the proper apportioning of the liquid to gas in the aeration "emulsion." Physical means include the solution or suspension of certain materials in the gas or liquid phase of the aeration emulsion.

The oxygen absorption coefficient of the solution may be used as an index of the ease with which the solution may be treated by the Ferric Sulphate process. The maximum capacity for converting sulphur is found when the solution has an iron concentration of about 5 grams per liter. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un 32mo
cop. 2

Serial No. 2840
November, 1927.

THE LIBRARY OF THE
JUL 23 1959
UNIVERSITY OF ILLINOIS

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

THE CARBURETION OF COMBUSTIBLE GAS WITH BUTANE AND PROPANE-BUTANE MIXTURES WITH PARTICULAR REFERENCE TO THE CARBURETION OF WATER GAS.

By Wm. W. Odell[1]

For a number of years there has been a very appreciable annual increase in the production and recovery of natural gas and natural-gas gasoline[2] in the United States the latter product being used largely for blending with gasoline from petroleum in the production of motor fuel. On account of the increased amount of oil cracking in the production of gasoline and the accompanying increased percentage of low-boiling constituents in the resulting product, the specifications for the natural gasoline suitable for blending have been altered, that is, the amounts of propane and butane which it can contain have been limited. The result has been that large quantities of the latter materials are wasted because there has been no ready market for them in large quantities. Because of this wasteage and because it is probable that large quantities of these and similar materials will be produced in the near future as a result of the more general use of oil cracking processes, a study was made by the Bureau of Mines, under a cooperative agreement with the assistance of the Phillips Petroleum Company, of the suitability of these materials alone or in mixtures for use as gas enricher in the carburetion of water gas for city distribution.

This investigation included:

(a) A study of the properties of the low boiling members of the paraffin series including pentane with particular reference to their utilization as gases.

(b) Calculations of the compositions and properties of gases of various heating values made with water gas as a base using chiefly butane and propane-butane mixtures as enriching materials.

(c) Consideration of the influence upon the numerous variable factors in the manufacture of carbureted gas of replacing gas oil (the present enriching material) by propane, butane or mixtures of the two.

---

[1] - Fuel Engineer, Bureau of Mines, Department of Commerce.
[2] - Including casing-head gasoline.

THE LIBRARY OF THE
JU
U

(d) An estimate of the influence of such a change upon certain important items of cost in the manufacture and distribution of carbureted gas.

(e) And, subsequent to the foregoing, tests were made in a small gas plant, using as enricher, by carburization without cracking, a product comprising chiefly butane but containing small amounts of propane and pentane, entirely replacing gas oil. This product was furnished by the Phillips Petroleum Company, and is named by them "G. E. Gasoline" meaning gas-enricher gasoline. The influence upon the important factors relating to the use of this product for enriching water gas was noted and the lean gas as well as the carbureted gas made was tested.

Some Properties of G. E. Gasoline
(Propane, butane, and mixtures of the two)

These hydrocarbons belonging to the same chemical series as methane, having the general formula C_nH_{2n+2}, have many chemical properties in common with methane and their addition to a lean gas changes the properties and burning characteristics of the gas in the same general direction although to a different extent. The hydrocarbons of this series do not readily enter into chemical reaction with other substances and therefore are incapable of combining with oxygen or polymerizing in the distributing system and thus cannot cause gum and resin troubles commonly met with in the distribution of manufactured gas.

As the number of carbon atoms in the molecule increases, i.e. in proceeding from methane throughout the series, the oxygen requirements for the complete combustion of unit volume of the gases also increases; in other words, the calorific values of these hydrocarbons (as gases) increases from methane. Similarly the specific gravity increases from methane in the same order. In Table 1 are shown some of the physical constants and properties of a few of these hydrocarbons which have bearing on their use for enriching gas.

It will be observed that both propane and butane are gases under normal conditions of temperature and pressure; accordingly it seems most feasible that they be stored under pressure and in the liquid form. Knowledge of the vapor pressures of these hydrocarbons at different temperatures is essential in making estimates relating to the feasibility of storing such products or the influence upon the cost of finished gas. Vapor pressure curves for some of the paraffin hydrocarbons are shown. Calculations have been made showing approximately the temperatures below which condensation would begin when these hydrocarbons are used as enricher in amounts varying from 2 to 12 per cent under pressure conditions varying up to 60 pounds and these data are shown in Table 2.

Table 1.- Some of the physical constants and properties of a few of the hydrocarbons of the paraffin series.

	Boiling point. Degrees Fahrenheit	Weight of liquid per gallon. Pounds.	Specific gravity of the gas at 60° F.	Cubic feet of gas per gallon of liquid at 60° F.	B.t.u. per gallon of liquid	B.t.u. per cubic foot of gas at 60° F. and 760 mm pressure.	Specific heat of gas at constant pressure B.t.u. per pound	Latent heat of vaporization of liquid		Calorific value B.t.u. per pound
								B.t.u. per gallon	B.t.u. per pound	
Methane, CH_4	-259	3.420	0.554	80.6	81,400	1008.4	0.593			23,790
Ethane, C_2H_6	-128	3.716	1.038	46.7	83.000	1763.6	0.506	792	213	22,240
Propane, C_3H_8	-47.4	4.462	1.523	38.2	96,900	2519	0.475	830	186	21,620
Butane, C_4H_{10}	+31.5	4.997	2.007	32.5	106,500	3274	0.458	854	170.8	21,320
Iso-butane--	+13.0									
Pentane C_5H_{12}	+96.9	5.214	2.491	27.3	110,200	4029	0.448	808	155	21,130
Hexane C_6H_{14}	+156.2	5.519	2.975	24.2	116,000	4784	0.442	790	143	21,010

Table 2.- Showing the temperatures Fahrenheit below which condensation begins (dew points) under 5 and 60 pound gauge pressures for certain individual paraffin hydrocarbons at concentrations of 2 to 12 per cent in water gas ($CO + H_2$).

	2 per cent		4 per cent		6 per cent		8 per cent		10 per cent		12 per cent	
	5 lbs.	60 lbs.	5 lbs.	60 lbs.	5 lbs.	60 lbs.	5 lbs.	60 lbs.	5 lbs.	60 lbs.	5 lbs.	60 lbs.
Methane (CH_4)	- 100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Ethane (C_2H_6)	- 100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Propane (C_3H_8)	- 100	-100	-100	- 95	-100	- 95	-100	- 80	-100	- 65	-100	- 65
Normal Butane (C_4H_{10})	- 95	- 55	- 80	- 30	- 70	- 20	- 55	- 10	- 50	0	- 40	+ 10
Iso-butane (C_4H_{10})	- 100	- 75	- 95	- 50	- 85	- 40	- 75	- 25	- 70	- 10	- 60	- 5
Normal Pentane (C_5H_{12})	0	+ 5	0	+ 32	0	+ 45	+ 5	+ 55	+ 12	+ 65	+ 22	+ 75
Iso- Pentane (C_5H_{12})	- 20	- 10	- 20	+ 20	- 20	+ 30	- 10	+ 40	0	+ 50	+ 10	+ 60

The above figures are based on calculations made with the use of vapor pressure charts and are believed accurate within the limits of accuracy required to illustrate the stability even at low temperatures of a gas such as water gas when enriched with propane, butane or mixtures of the two in amounts required to bring the former up to city gas standards and when the pressure conditions are those normally used in the distribution of city gas. No allowance has been made for solubility effect resulting from the absorbtion of hydrocarbons by drip condensate which might result when the carbureted gas is mixed with other gases containing condensable matter.

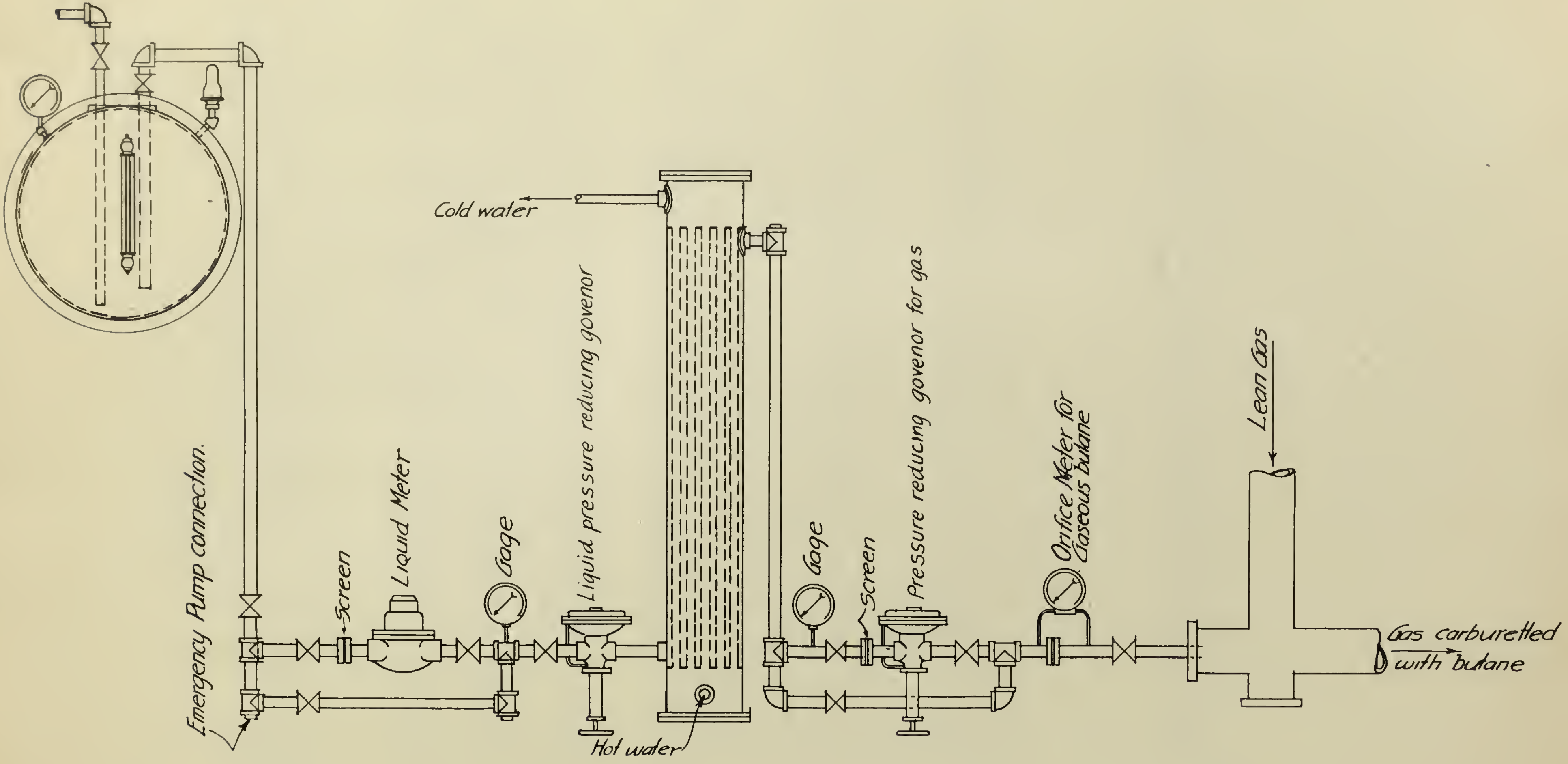

Cold water
Emergency Pump connection.
Screen
Liquid Meter
Gage
Liquid pressure reducing govenor
Hot water
Gage
Screen
Pressure reducing govenor for gas
Orifice Meter for Gaseous butane
Lean Gas
Gas carburetted with butane

Fig.1 -

Showing diagramatically a means for using G. E. Gasoline as enricher, similar to that used in the experiments at Muscatine.

Procedure

The calculations and preliminary study of the properties of these hydrocarbons indicated that they could be used satisfactorily for enriching lean gas and that the problem was chiefly a mechanical rather than a chemical problem. Means were developed for uniformly introducing the new enricher as a gas into the lean gas.

The water gas set[3] was operated in the normal manner, using West Virginia coal as generator fuel, making the usual blow runs, but gas oil was not admitted to the carburetor although the blast gas was largely burned therein as usual. The lean gas comprising mixed water gas and blow-run gas was conducted directly to the relief holder uncarbureted. This lean gas was subsequently enriched while still warm at the outlet of the relief holder, from which it was withdrawn quite uniformly by the works exhauster, by the introduction of the gasified gasoline using approximately 9.2 per cent of the latter by gas volume in the production of 565 B.t.u. gas.

The gasoline was used directly from a tank car in which it was under 35 pound pressure. The liquid was withdrawn under its own vapor pressure and caused to pass through pressure reducing regulators, through a vaporizer wherein it was gasified, through an orifice meter and the pipe line connecting it with the lean unpurified gas. The vaporizer used comprised a simple and small, metal-tube heat exchanger in which some of the hot water overflowing from the condenser was the heating medium. The latent heat of vaporization of the gasoline was low as shown in Table 1, hence the high capacity of a small heat exchanger. The hook-up used at Muscatine is substantially and diagrammatically as shown in Figure 1.

A Parr recording calorimeter was used and also a Sargent calorimeter in determining the heating value of the gas. Analyses were made of the lean and of the carbureted gases. In Table 3 the composition and calorific values of these gases are shown.

---

[3] - This work was done, through the courtesy of the officers of the United Light and Power Company and the assistance of their engineers, at Muscatine, Iowa.

Table 3.- Showing the composition and calorific value of the finished, butane-carbureted gas and of the lean gas as made at Muscatine, using West Virginia coal as generator fuel.

	Finished gas *	Lean gas	
		Mixed blue gas and blow-run gas.	
CO_2 - - - - - - - - - - - - - - - - - - -	7.72	8.6	8.6
Illuminants - - - - - - - - - - - - -	.88	1.4	1.0
O_2 - - - - - - - - - - - - - - - - - - -	.40	.0	.1
CO - - - - - - - - - - - - - - - - - - -	22.62	26.4	25.5
H_2 - - - - - - - - - - - - - - - - - - -	29.00	32.7	32.7
CH_4 - - - - - - - - - - - - - - - - - - -	6.30	5.1	7.1
Butane-(enricher gas) - - - - - - - -	9.18	----	----
N_2 - - - - - - - - - - - - - - - - - - -	23.90	25.8	25.0
Calculated B.t.u. - - - - - - - - - -	567	----	----
Actual B.t.u. as shown by calorimeter	565	----	----
Specific gravity	0.814 (determined)		

* Some air was added at the exhauster (common practice at this plant) for the purpose of aiding purification.

Results

The main report of this investigation which will be a forthcoming publication of the Bureau of Mines will present in more detail the calculations and results of this study. For the purposes of this report the following summary and conclusions which in part alludes to the more complete report and which represents in substance the summary and conclusions of the latter, will probably suffice as a statement of results.

Summary and Conclusions

As a result of a study of some of the important properties of the highly volatile members of the paraffin series particularly those properties pertinent to the generation, distribution and utilization of manufactured gas and as a result of the commercial production of carbureted water gas for a brief period only in a small gas works, using those hydrocarbons as enricher it seems that some quite definite conclusions are justified relating to the possibilities in the commercial utilization of these materials for such a purpose. The following summary is made along with certain conclusions some of which latter may require some modification which is not apparent now and which may become evident after prolonged usage of the new enricher.

One grade of G. E. Gasoline comprising chiefly a mixture of normal and iso-butane, but containing approximately 5 per cent of propane and 2 per cent of pentane was used on a commercial scale in the production of carbureted water gas having a calorific value of 565 B.t.u. per cubic foot, the gasoline entirely replacing gas oil, and it was noted that:

(A) There were no complaints of service or quality of gas supplied the consumers.

(B) The quality of the gas made and distributed was readily maintained at the approved standards.

(C) As indicated by the calorific value of the gas at points distant from the gas works the condensation in the mains and distributing system was nil. As a matter of fact this observation was partly obscured since the calorific value of the gas at these outlying points was appreciably higher than that of the gas sent out from the gas works; this difference obviously being due to a removal from the distributing system of accumulations of condensed matter including naphthalene, which would logically follow as a result of the difference in the partical pressures of naphthalene and the like in the 2 kinds of carbureted gas, namely the gases made using gas oil and using the gasoline as enrichers. Prolonged operation using G. E. Gasoline may show that there is a certain amount of condensation in the distributing system, but it is evident that under normal conditions the amount of this condensate will be small and it will not comprise propane, butane and pentane.

(D) The candle power of the finished gas (enriched with G. E. Gasoline) as revealed by mere observation of the gas when burning from a flat-flame burner-tip was somewhat lower than that of ordinary carbureted water gas of the same calorific value when similarly burned. A photometer was not available for making this test but it is believed and appears to be true that this difference in luminousity of the flat-flame jet is of little if any importance in the manufacture of city gas.

(E) The specific gravity of the finished gas distributed during the operation with G. E. Gasoline was rather high being 0.76 to 0.82. However, in this connection it will be noted that it has been the practice at this plant to distribute gas containing a high percentage of inerts - - - $CO2 + N_2$ - - - taking advantage of the economies resulting from the use of the blow run, the density of this gas normally being higher than in those plants making either mixed coal gas and water gas or carbureted water gas containing a lower percentage of inerts. Calculations have been made showing that the density of finished, carbureted water-gas using G. E. Gasoline as enricher need be only slightly greater than that made in the regular way using gas oil, other factors remaining the same.

(F) The composition of the lean gas (mixed blow-run gas and water gas) and of the finished gas made during these tests are shown. In this connection attention is called to the fact that the lean gas was made in a hand operated carbureted water gas set, with a generator-shell 5 feet 6 inches in diameter, using Boone Chilton coal. Approximately 9.2 per cent of G. E. Gasoline (gas) was required in the finished gas carbureted to 565 B.t.u. per cubic foot. This is a smaller volume than that of the oil gas resulting from cracking the gas oil used in the ordinary carburetion of water gas, therefore a greater amount of lean gas must be made per M. of finished standard gas when using G. E. Gasoline than when using gas oil; this results in a direct decrease in gas-making capacity unless operating changes are made to "offset" this difference. In the early part of the operation at Muscatine, Iowa, no such changes were attempted and the capacity was accordingly reduced approximately 10 per cent, but subsequently the gas making capacity was raised above normal with satisfactory results.

(G) A small amount of tar - - - in this case, coal tar - - - was produced in the operation of the water gas set, the duration of the tests being too short to measure accurately the quantity which obviously must be very small. It was noted, however, that the tar formed had a high specific gravity and settled readily from water without exhibiting a tendency to form emulsions.

(H) The generator fuel per M. of carbureted gas made increases substantially in proportion to the increased amount of blue gas in the finished product. In some of the tests the increase was a little more than this amount for reasons which were evident and could not readily be avoided. Operating data including the fuel used per M. are shown.

(1) The water gas set was operated in the regular manner making water gas and blow-run gas, but enricher was not introduced into the carbureter; lean gas was conducted to the relief holder and vaporized G. E. Gasoline was introduced into this gas at a uniform rate as it was withdrawn from the holder. The blast gas was almost entirely burned in the usual manner in the checker chambers by the introduction of secondary air causing the temperature at the base of the superheater to rise to 1800° F. and that at the top of the carburetor to reach approximately 1900° F. It was believed that at such temperatures much of the tar liberated by the coal during the gas making period would be cracked and gasified. In fact it seems that at 1800° to 1900° F. some of the carbon from the tar and from any blown-over fuel should combine with steam (always present in excess in generator gas) by the water gas reaction. The extent to which this actually happened is obscured by the lack of uniformity in the lump size of the coal used.

(2) Calculations have been made to show the amount of G. E. Gasoline required per M. of finished gas having calorific values varying from 475 to 600 B.t.u. per cubic foot using the blow run to the extent of zero to 30 per cent. Graphs showing these relations and the density of the finished gas are shown for 2 grades of G. E. Gasoline. (See Figure 2).

(3) The most satisfactory method of introducing G. E. Gasoline into the lean gas for carbureting purposes will depend somewhat upon plant conditions; a few simple means for accomplishing this have been shown and discussed.

(4) Calculations indicate that substantial economies can be made in the manufacture and distribution of carbureted water gas by the substitution of G. E. Gasoline (cold carburetion) for gas oil at the same price as gas oil; these economies include:

(a) A decrease in the consumption of enricher per M. of gas made resulting from the higher calorific value per cubic foot of G. E. Gasoline gas than that of the gas resulting from the cracking of gas oil.

(b) A decrease in the consumption of enricher per M. of gas made because of decreased condensation in the distributing system; the gas as made with G. E. Gasoline can have a calorific value 10 to 15 B.t.u. per cubic foot less at the gas works than the ordinary carbureted gas of a given standard without altering the quality of the gas as supplied to the consumers at distant points.

FIG. II

93% BUTANES
2% PENTANES
5% PROPANE

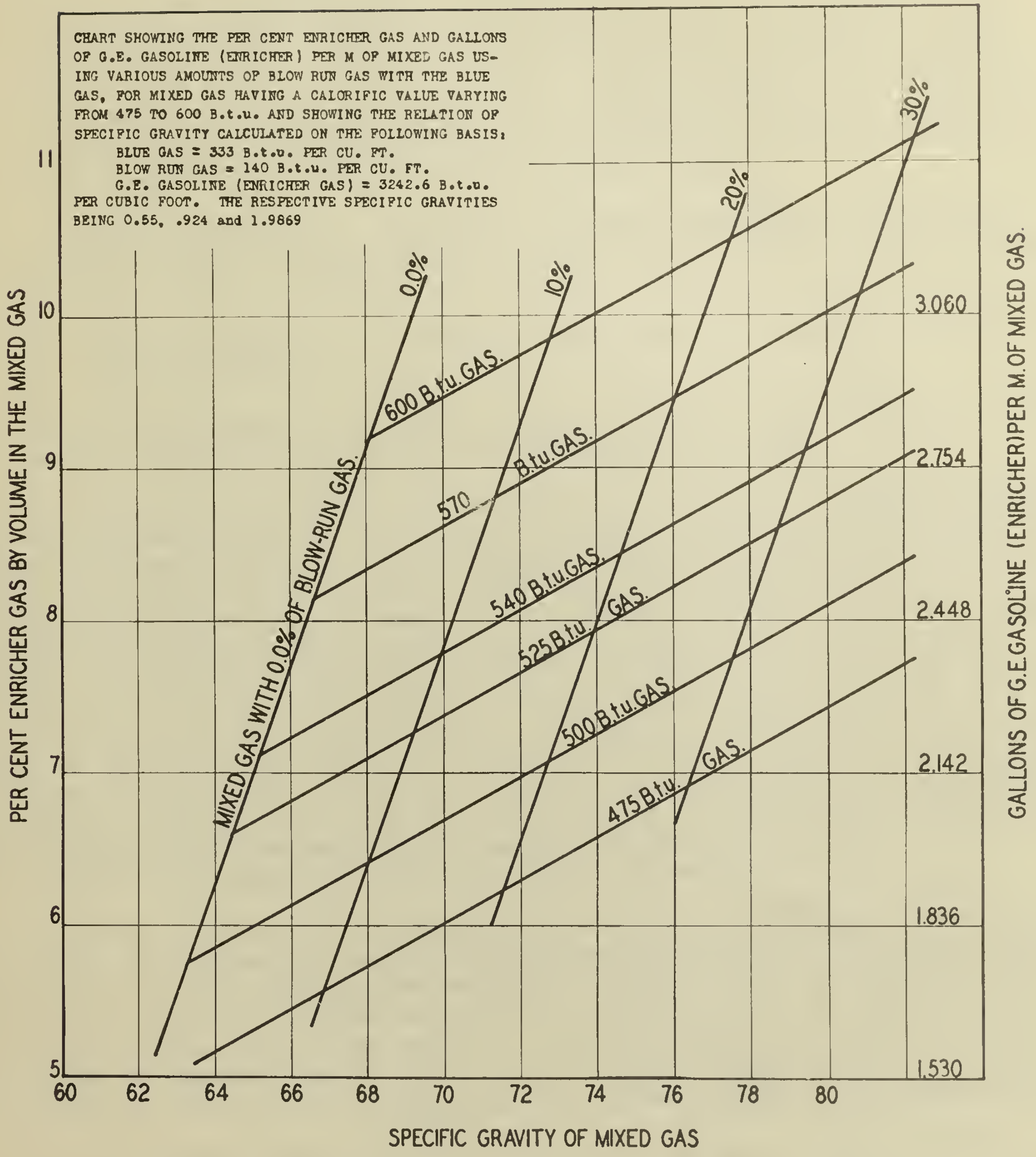


CHART SHOWING THE PER CENT ENRICHER GAS AND GALLONS OF G.E. GASOLINE (ENRICHER) PER M OF MIXED GAS USING VARIOUS AMOUNTS OF BLOW RUN GAS WITH THE BLUE GAS, FOR MIXED GAS HAVING A CALORIFIC VALUE VARYING FROM 475 TO 600 B.t.u. AND SHOWING THE RELATION OF SPECIFIC GRAVITY CALCULATED ON THE FOLLOWING BASIS:

BLUE GAS = 333 B.t.u. PER CU. FT.
BLOW RUN GAS = 140 B.t.u. PER CU. FT.
G.E. GASOLINE (ENRICHER GAS) = 3242.6 B.t.u. PER CUBIC FOOT. THE RESPECTIVE SPECIFIC GRAVITIES BEING 0.55, .924 and 1.9869

PER CENT ENRICHER GAS BY VOLUME IN THE MIXED GAS
5
6
7
8
9
10
11
60
62
64
66
68
70
72
74
76
78
80
SPECIFIC GRAVITY OF MIXED GAS
GALLONS OF G.E.GASOLINE (ENRICHER)PER M.OF MIXED GAS.
1.530
1.836
2.142
2.448
2.754
3.060
0.0%
10%
20%
30%
MIXED GAS WITH 0.0% OF BLOW-RUN GAS.
600 B.t.u.GAS.
570 B.t.u.GAS.
540 B.t.u.GAS.
525 B.t.u. GAS.
500 B.t.u.GAS.
475 B.t.u. GAS.

(c) A decrease in the cost of purifying raw gas because of the decreased amount of naphthalene and tar and possibly of sulphur compounds present. In small plants where oxide is frequently prematurely discarded because of the presence of an excessive amount of tar, the "life" of the oxide and its capacity for removing H_2S should be increased when using the new enricher. The G. E. Gasoline used in the tests was free from H_2S and contained 0.5 grains of organic sulphur compounds per 100 cubic feet of vapor. With this quality of enricher comprising paraffin hydrocarbons it is possible not only to make a gas which is substantially free from sulphur compounds (organic and inorganic) but the gas should be equally devoid of the gum-forming and resin-forming compounds which have been so annoying in many gas plants in recent years.

(d) An increase in the amount of available waste heat which can be utilized in heat economizers or by a modification of the operating method such as by the use of back run.

(e) A decrease in the expense resulting from the checkering of the carbureting chambers.

(f) A decrease in the cost of handling and caring for complaints of service resulting from naphthalene stoppages and the like.

(5) Some of the important items relating to the cost of manufactured gas have been discussed herein. It is recognized that normally the chief items tending to increase the cost of the finished gas are a decreased credit from the sale of tar and an increase in the generator fuel requirements. The cost of storing G. E. Gasoline, and it must be stored under pressure, is an item to which an approximate value has been assigned. In some plants where the gas-making capacity is reduced a proportional increase in the direct gas-generating labor will result. In spite of these facts it is believed that the net result of the change from gas oil to G. E. Gasoline as enricher at a common price will be an economy in the average gas works. In making the latter statement it is recognized that in some plants, namely those in which high oil-gasification efficiency is obtained, in which the tar and drip oil are sold at a high price and which are well equipped for the removal of tar, naphthalene and H_2S, it may not be an economy to use G. E. Gasoline at the same price as gas oil.

(6) The properties of G. E. Gasoline and of the individual low-boiling hydrocarbons of the paraffin series are discussed and graphs are presented showing the vapor pressure-temperature relations. Attention has been called to the fact that consideration must be given to the properties of G. E. Gasoline when unloading, pumping, storing and using it. In visualizing the nature of this product it may be likened to water stored in a tank at a temperature above its boiling point under pressure - - - being a gas at ordinary temperatures and pressures.

(7) In making comparisons in this paper it has been assumed that the average oil-gasification efficiency in gas works practice is equivalent to 100,000 B.t.u. per gallon of gas oil. With a good grade of gas oil a higher efficiency than this is sometimes obtained; in many of the small plants the oil-gasification

efficiency is lower than this. It is believed probable that with an increasing amount of oil cracking in the production of gasoline the quality of oil available for the generation of gas will be of such a quality that it may be difficult to obtain results as good as 100,000 B.t.u. per gallon. With this in mind, in view of the general trend in the price of gas oil over a period of years it appears that the economies possible in the substitution of G. E. Gasoline for gas oil at a common price will increase with time. Of the two grades of G. E. Gasoline considered herein, one comprising chiefly propane and butane in equal liquid volumes, yields approximately 101,700 B.t.u. per gallon to the gas, the other comprising chiefly butane yields approximately 106,100 B.t.u. per gallon.

(8) Data are presented showing the annual march of prices of crude oil and gas oil in the Mid-continent field for a period of years. The amounts of natural gas and natural gas gasoline produced and recovered annually in the United States for a period of years are shown affording a means for visualizing approximately the possible and probable production of G. E. Gasoline in this country from this source. Petroleum technologists state that a large production of low boiling hydrocarbons will result from and accompany the more extensive use of cracking processes in the production of gasoline.

(9) In the experimental operation at Muscatine, Iowa, the G. E. Gasoline was introduced into the lean gas in the gaseous state, a simple, small, tubular heat exchanger being used to vaporize the gasoline, hot water from the condenser being the source of heat. It will be noted that the latent heat of vaporization of G. E. Gasoline is low and therefore a small amount of heat only is required for its vaporization.

Table 4.- Properties of three grades of gas enricher produced by Phillips Petroleum Co.

	GRADE 1	GRADE 2	GRADE 3
Vapor Pressure Lbs. per Sq.In. gauge			
at 70°F	33	70	120
at 90°F	50	100	165
at 100°F	60	135	195
at 130°F	100	185	300
Boiling Point at 14.7 lbs. per sq.in. absolute	+15°F	-19°F	-42°F
Specific gravity of liquid (water = 1)	.577	.55	.515
A.P.I. gravity of liquid	114	126	143°
Weight per gallon of liquid	4.8	4.58	4.24#
Specific gravity of gas (air = 1)	1.95	1.77	1.55
Cubic feet of gas per gallon of liquid	32	33.8	36
Heating Value			
B.t.u. per cu.ft.	3,190	2,910	2,550
B.t.u. per lb.	21,350	21,450	21,600
B.t.u. per gallon	102,400	98,300	93,000
Latent Heat of Vaporization at Boiling Pt.			
B.t.u. per lb.	170	177	183
B.t.u. per gallon	830	810	790
Specific Heat of vapor (Cp)	.46	.465	.475
Dew Point at 14.7 lbs. absolute	+26°F	+10°F	-45°F
Temperature at which pressure is 0 lbs. per sq. in. gauge	+15°F	-20°F	-45°F

These properties are approximate only and can be readily varied to meet exact specifications or customers' requirements, by slight changes in the composition of the various grades.

Author's note: The gasoline designated as grade 1 above is substantially like that used in the large scale tests at Muscatine, Iowa. In the calculations upon which Figure 2 is based, the calorific value of the gasoline vapor and the yield of vapor per gallon of liquid are assumed to be somewhat higher than the figures given in the above table.

Acknowledgements

Grateful acknowledgement is made for helpful suggestions offered by Messrs. G. G. Oberfell, Director of Research of Phillips Petroleum Company and O. P. Hood, Chief of Technologic Division of the Bureau of Mines. The hearty cooperation of the officials and representatives of the United Light and Power Company was appreciated; their engineers and chemists actively assisted in the experimental work. Messrs. R. W. Thomas and F. J. Harlow of the Research Staff of Phillips Petroleum Company also actively and helpfully assisted in this work. Appreciation is also expressed for the service rendered by Professor Parr who at his own expense installed the Parr recording calorimeter which was used throughout the tests. - Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un 32mo
cop. 2

Serial No. 2841
November, 1927

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - - BUREAU OF MINES

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

COAL-MINE FATALITIES IN OCTOBER, 1927.

By W. W. Adams[1]

Fatal accidents at coal mines in the United States during October, 1927, caused the death of 177 men, 39 less than in October last year, according to information furnished by State mine inspectors to the United States Bureau of Mines, Department of Commerce. Forty of the fatalities were at anthracite mines in Pennsylvania and 137 were at bituminous mines in all States. Included in the figures for October last year are 27 fatalities resulting from an explosion at Rockwood, Tenn., and 9 fatalities resulting from an explosion at Nanticoke, Pa. There were no major disasters in October 1927.

The production of coal during October included 44,000,000 tons of bituminous and 7,404,000 tons of anthracite. The fatality rate for the month was 3.11 per million tons for bituminous mines and 5.40 for anthracite mines, with a rate of 3.44 for both classes of mines combined. The corresponding rates for October last year were 3.34 for bituminous mines, 4.06 for anthracite mines, and 3.44 for both classes combined. The combined rate for both classes of mines was the same in October of both years.

The year 1927 to the end of October shows a total of 1,825 fatalities and an output of 505,641,000 tons of coal, the fatality rate being 3.61 per million tons. The corresponding period of last year showed 2,037 fatalities and 526,536,000 tons of coal with a death rate of 3.87. The 10-month rate for 1927 therefore represents an improvement of 7 per cent over the corresponding period last year. The records for the first ten months of 1927 for bituminous mines show 1,418 deaths, 437,921,000 tons of coal produced and a death rate of 3.24; similar records for anthracite mines show 407 deaths, 67,720,000 tons of coal and a death rate of 6.01. These figures indicate an improvement for bituminous mines and a set-back for anthracite mines, the bituminous rate last year being 3.66 and the anthracite rate 5.22

Eight major disasters thus far in 1927 have resulted in the loss of 155 lives, as compared with 14 major disasters causing 306 deaths during the corresponding ten months of 1926. The death rates per million tons based exclusively on major disasters stands at 0.307 for 1927 and 0.581 for 1926.

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

Considering all classes of accidents, the net fatality rate for 1927 is lower than for the 10-month period of 1926. Lower death rates in 1927 are shown for falls of roof and coal, for haulage accidents, and for explosions. Slight increases are indicated by the rates for explosives and electricity. These facts are shown in the following figures, which cover both anthracite and bituminous coal mines:

	Year 1926	Jan.-Oct. 1926	Jan.-Oct. 1927
All causes	3.790	3.869	3.609
Falls of roof and coal	1.829	1.840	1.798
Haulage	.650	.667	.564
Gas or dust explosions:			
Local explosions	.111	.116	.144
Major explosions	.525	.581	.293
Explosives	.145	.133	.180
Electricity	.143	.152	.176

Tables 1 to 4 inclusive, present a detailed statistical comparison of the number and causes of accidents and corresponding rates in 1927 with similar figures for earlier years. Table 5 shows the fatality rates per million tons of coal produced, by months and causes of accidents for the ten-year-period 1917-1926. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE 1 - NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES

(Includes both anthracite and bituminous coal)

	Year 1926	Jan.-Oct. 1926	Jan.-Oct. 1927
Falls of Roof & Coal..................	1.829	1.840	1.798
At face........................	1.386	1.418	1.327
In room........................	.238	.226	.243
On entry.......................	.193	.188	.216
On slope.......................	.012	.008	.012
Haulage............................	.650	.667	.564
Switching and spragging............	.020	.017	.012
Coupling...........................	.008	.008	.024
Falling from trips.................	.030	.025	.032
Run over...........................	.241	.249	.223
Caught between car and rib..........	.136	.142	.150
Caught between car and roof.........	.027	.027	.034
Runaway cars.......................	.057	.057	.049
Miscellaneous......................	.131	.142	.040
Gas or Dust Explosions..............	.636	.637	.437
Open light.........................	.191	.165	.077
Defective safety lamp..............	.005	.006	.002
Electric arc.......................	.081	.095	.055
Shot...............................	.077	.091	.026
Powder explosion...................	.005	.006	.006
Miscellaneous......................	.277	.334	.271
Explosives.........................	.145	.133	.180
Transportation.....................	-----	-----	.002
Charging...........................	.006	.008	.004
Suffocation........................	.008	.004	-----
Drilling into old holes............	.003	.004	-----
Striking in loose rocks............	-----	-----	-----
Thawing............................	-----	-----	-----
Caps & detonators..................	.001	.002	.006
Unguarded shots....................	.006	.004	.006
Returned too soon..................	.013	.013	.016
Premature shot.....................	.048	.042	.075
Sparks from lamp, etc..............	.005	.006	.006
Delayed shots......................	.015	.013	.012
Shot breaking through rib..........	.011	.009	.018
Miscellaneous......................	.029	.028	.035
Electricity........................	.143	.152	.176
Direct contact with trolley wire.....	.050	.051	.073
Tools striking trolley wire..........	.003	.004	.004
Contact with mining machine..........	.013	.011	.018
Contact with machine feed wire.......	.009	.008	.024
Contact with haulage motor...........	.003	.004	.002
Miscellaneous......................	.065	.074	.055

TABLE 2 - COAL-MINE FATALITIES DURING OCTOBER, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																													
Falls of roof.............	12	-	-	-	5	-	-	-	6	-	-	1	3	1	-	-	3	11	-	1	-	2	3	2	27	1	78	13	91
Falls of side.............	1	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1	-	-	-	7	1	8
Haulage..................	1	-	-	1	1	2	-	-	1	-	-	1	-	1	-	-	-	3	-	1	-	-	-	-	13	-	25	4	29
Gas or dust explosions.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2	-	4	7	11
Explosives...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	7	8
Suffocated by mines gases..	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electricity..............	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	-	1	-	1	-	-	1	-	2	-	8	1	9
Animals..................	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Mining machines...........	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	3	-	3
Mine fires...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes..............	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	4
TOTAL..........	14	-	-	2	10	3	1	-	8	-	-	2	3	2	-	-	5	20	-	3	-	2	5	2	45	1	128	36	164
SHAFT																													
Persons falling...........	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3
Objects falling...........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cages, skips..............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1
Other causes..............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL..........	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	4	-	4
SURFACE																													
Mine cars................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	2	3
Electricity..............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	2
Machinery................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boiler explosions.........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Railway cars..............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes..............	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	3	1	4
TOTAL..........	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	1	-	-	-	-	-	-	1	-	5	4	9
GRAND TOTAL, Oct., 1927....	14	0	0	2	10	4	1	1	8	1	0	3	3	2	0	2	5	21	0	3	0	2	5	2	47	1	137	40	177
GRAND TOTAL, Oct., 1926....	10	0	2	4	12	5	1	2	15	1	0	2	0	0	0	6	1	34	0	27	0	1	10	1	46	0	181	35	216

TABLE 3 - COAL-MINE FATALITIES DURING 1927 AND 1926, BY MONTHS AND STATES.

MONTH	Ala	Alas	Ark	Col	Ga. & N.C.	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January...............	6	–	2	8	–	19	3	1	–	23	–	1	1	1	2	–	7	2	36	–	3	–	1	2	1	43	4	166	46	212
February..............	7	–	2	5	–	11	6	1	2	10	–	–	–	1	2	2	9	2	31	–	–	–	5	5	2	35	–	138	41	179
March.................	6	–	–	7	–	23	7	1	2	6	–	–	–	–	2	–	6	2	35	–	3	–	2	3	1	38	1	145	42	187
April.................	6	–	–	2	–	4	–	2	–	2	–	1	–	1	–	–	3	2	33	–	1	–	3	3	7	144	–	214	41	255
May...................	6	–	1	8	–	4	–	1	–	11	–	–	–	–	1	–	5	1	25	–	–	–	3	9	2	50	1	128	53	181
June..................	4	–	1	3	–	–	2	–	1	5	1	–	–	2	3	–	3	2	29	–	–	–	2	1	1	53	1	114	52	166
July..................	11	–	1	1	–	–	1	–	1	17	1	–	–	–	–	–	5	3	25	–	3	–	1	–	1	35	1	107	30	137
August................	9	–	1	4	–	2	1	2	1	30	–	–	–	1	2	–	3	–	34	–	5	–	1	5	1	37	5	142	26	168
September.............	6	–	–	4	–	3	4	–	2	16	1	–	1	1	2	–	5	3	31	–	1	2	1	3	1	38	2	127	36	163
October...............	14	–	–	2	–	10	4	1	1	8	1	–	3	3	2	–	2	5	21	–	3	–	2	5	2	47	1	137	40	177
TOTAL, 10 months, 1927.	75	0	8	44	0	76	28	9	10	128	4	2	5	10	16	2	48	22	300	0	17	2	21	36	19	520	16	1,418	407	1,825
TOTAL, 10 months, 1926.	120	1	5	40	1	120	34	8	14	149	12	1	6	3	12	1	64	121	340	0	45	0	17	46	7	488	19	1,674	363	2,037
TOTAL, 1926.......	139	1	7	53	3	166	78	16	17	178	12	1	9	5	13	1	80	124	420	0	50	0	20	58	15	573	22	2,061	453	2,514

TABLE 4 - AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED

Cause of accident	Per cent of total 1917-1926	Death rates per million short tons						
		Average for 10 years 1917-1926	Year 1925	Year 1926	Average for Oct. 10 years 1917-1926	1927		1926
						Sept.	Oct.	Oct.
		Bituminous Mines						
1. Falls of roof and coal	48.96	1.759	1.750	1.717	1.702	1.788	1.932	1.699
2. Underground haulage.	18.18	.653	.586	.655	.603	.453	.568	.536
3. Explosions of gas or coal dust:								
Local explosions	2.91	.104	.112	.080	.098	.048	.091	.037
Major explosions	10.84	.390	.469	.565	.081	- - -	- - -	.499
4. Explosives	3.30	.118	.094	.080	.104	.048	.023	.074
5. Electricity.	4.01	.144	.154	.161	.161	.190	.182	.148
6. Mining machines.	1.33	.048	.067	.045	.041	.024	.068	.037
7. Other causes underground . . .	2.93	.105	.089	.067	.126	.095	.045	.092
8. All causes underground	92.46	3.321	3.321	3.370	2.916	2.646	2.909	3.122
9. All shaft accidents.	1.73	.062	.058	.047	.057	.048	.091	.056
10. All accidents on surface . . .	5.81	.209	.148	.147	.183	.334	.114	.166
11. All accidents.	100.00	3.592	3.527	3.564	3.156	3.028	3.114	3.344
		Anthracite Mines						
1. Falls of roof and coal	42.71	2.496	2.750	2.588	2.317	3.011	1.890	2.205
2. Underground haulage.	12.75	.745	.906	.612	.728	.301	.540	.232
3. Explosions of gas:								
Local explosions	6.71	.392	.421	.329	.291	.753	.946	- - -
Major explosions	1.51	.088	.275	.247	.119	- - -	- - -	1.045
4. Explosives	12.37	.723	.857	.588	.410	.602	.946	.232
5. Electricity.	1.00	.059	.065	.024	.040	- - -	.135	- - -
6. Other causes underground . . .	8.18	.478	.323	.459	.371	.452	.405	.116
7. All causes underground	85.23	4.981	5.597	4.847	4.276	5.119	4.862	3.330
8. All shaft accidents.	2.30	.134	.065	.094	.106	- - -	- - -	- - -
9. All accidents on surface . . .	12.47	.729	.809	.388	.530	.301	.540	.232
10. All accidents.	100.00	5.844	6.471	5.329	4.912	5.420	5.402	4.062

TABLE 5 - TEN-YEAR AVERAGE FATALITY RATES PER MILLION TONS OF COAL PRODUCED, BY MONTHS AND CAUSES OF ACCIDENTS, 1917-1926

Cause of accident	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.
Bituminous Mines										
1. Falls of roof and coal	1.774	1.750	1.609	1.924	1.668	1.927	1.869	1.843	1.744	1.702
2. Underground haulage.	.655	.671	.654	.702	.683	.650	.726	.691	.597	.603
3. Explosions of gas or coal dust:										
Local explosions	.121	.137	.104	.097	.093	.136	.077	.078	.057	.098
Major explosions	.483	.607	.704	.773	.221	.118	.109	.622	.198	.081
4. Explosives	.153	.125	.115	.125	.107	.103	.127	.108	.133	.104
5. Electricity.	.133	.125	.099	.116	.146	.189	.234	.175	.168	.161
6. Mining machines.	.059	.056	.037	.065	.062	.033	.045	.057	.037	.041
7. Other causes underground . . .	.110	.113	.092	.099	.122	.111	.082	.106	.087	.126
8. All causes underground	3.488	3.584	3.414	3.901	3.102	3.267	3.269	3.680	3.021	2.916
9. All shaft accidents.	.053	.068	.044	.060	.026	.063	.060	.080	.087	.057
10. All accidents on surface . . .	.197	.218	.202	.241	.208	.224	.281	.250	.172	.183
11. All accidents.	3.738	3.870	3.660	4.202	3.336	3.554	3.610	4.010	3.280	3.156
Anthracite Mines										
1. Falls of roof and coal	2.716	2.419	2.477	2.761	2.477	2.551	2.850	2.241	1.927	2.317
2. Underground haulage.	.822	.925	.826	.720	.670	.646	.797	.720	.721	.728
3. Explosions of gas:										
Local explosions	.382	.293	.283	.390	.424	.632	.392	.414	.436	.291
Major explosions	- - -	.077	.062	- - -	.164	.257	.202	.133	- - -	.119
4. Explosives	.705	.508	.628	.660	.479	1.330	.783	.654	.620	.410
5. Electricity.	.044	.062	.024	.030	.027	.094	.094	.120	.134	.040
6. Other causes underground .	.440	.524	.419	.435	.712	.471	.554	.494	.486	.371
7. All causes underground	5.109	4.808	4.719	4.996	4.953	6.581	5.672	4.776	4.324	4.276
8. All shaft accidents.	.220	.169	.185	.105	.219	.094	.149	.027	.117	.106
9. All accidents on surface . . .	1.160	1.187	.641	.615	.465	.606	.851	.640	.587	.530
10. All accidents.	6.489	6.164	5.545	5.716	5.637	7.281	6.672	5.443	5.028	4.912

622.09
Un 32 mo
cop. 2

Serial No. 2842
November, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

CONSUMPTION OF EXPLOSIVES IN OCTOBER, 1927

By W. W. Adams[1]

The amount of explosives sold in the United States during October 1927 for American consumption was 580,000 kegs (14,500,000 pounds) of black blasting powder, 6,336,000 pounds of permissible explosives, and 26,322,000 pounds of high explosives other than permissibles. These figures are based on reports from manufacturers to the Bureau of Mines, Department of Commerce, and include an estimate of sales by several companies that do not furnish monthly reports. Statements actually received from the reporting manufacturers showed sales of 568,535 kegs of black powder, 6,326,338 pounds of permissibles, and 24,732,145 pounds of other high explosives.

October sales of black powder were more than in the preceding month but less than in October last year. Sales of permissibles were also more than in the preceding month but less than in the corresponding month a year ago. Sales of other high explosives were less than in September and were also less than in October last year. Total sales of all three classes of explosives during the first ten months of 1927 were somewhat smaller in volume than during the corresponding period of 1926.

PERMISSIBLE EXPLOSIVES: Permissibles sold in October made the total sales thus far in 1927 reach 53,761,000 pounds including 53,681,100 pounds actually reported to the Bureau, and an estimate of the small quantity unreported. The quantity sold during the 10-month period January to October 1927 was slightly less than that sold during the same period in 1926. Nearly 96 per cent of these explosives were used in coal mining, 67 per cent being used in bituminous mines and 29 per cent in anthracite mines. During the 10-month period the amount used at bituminous mines averaged 82 pounds of permissibles, or 29 per cent of the 282 pounds of all kinds of explosives per thousand tons of bituminous coal produced. The record for anthracite mines shows 754 pounds of all kinds of explosives per thousand tons of coal produced, of which 230 pounds, or 31 per cent, were permissibles. The large coal-producing States of Pennsylvania, West Virginia, Alabama, Kentucky, and Illinois used 88 per cent of the entire amount of this class of explosives.

BLACK BLASTING POWDER: October sales for this class of explosives brought the total sales to 4,390,400 kegs, including 4,302,661 kegs sold by reporting companies and an estimate for those companies that do not send their monthly sales figures to the Bureau of Mines. A decrease of 12 per cent in the sales during this period of ten months in 1927 is noted when compared with the sales during the same period in 1926. Eighty-four per cent of the total quantity was used in coal mines, 73 per cent being for bituminous mines and 11 per cent for anthracite mines. The remaining 16 per cent was used in the metal-mining and quarrying industry, in railway and other construction work, and for miscellaneous purposes. The consumption of black blasting powder in coal mines since January first has averaged 183 pounds, or 65 per cent, of a total of 282 pounds of all kinds of explosives per thousand tons of bituminous coal produced. The average consumption in anthracite mines was 183 pounds, or 24 per cent, of the 754 pounds of all classes of explosives used for each thousand tons of coal produced. Pennsylvania, Kentucky, Illinois, West Virginia, Indiana, and Ohio continue to be the leading States in the use of this class of explosives, their sales amounting to 60 per cent of the total quantity used during the first ten months of the present year.

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

OTHER HIGH EXPLOSIVES: The amount of this class of explosives sold in the period January to October 1927 was 259,962,000 pounds, a slight decrease when compared with the quantity sold during the same 10-month period in 1926. This figure includes 244,239,850 pounds actually reported and an estimate of sales by non-reporting companies. Metal mining used 30 per cent of the total quantity sold during this ten-month period; quarrying and nonmetallic mineral mining used 28 per cent; coal mining used 12 per cent (9 per cent by anthracite mines and 3 per cent by bituminous mines); the 30 per cent remaining was used for railway and other construction work, and for miscellaneous purposes. The quantity of powder used at anthracite mines since January has averaged 341 pounds per thousand tons of coal produced, or 45 per cent of the 754 pounds of all kinds of explosives per thousand tons. The quantity used at bituminous coal mines was 17 pounds of high explosives, or 6 per cent of the 282 pounds of all kinds of explosives used per thousand tons of coal produced. Pennsylvania, Michigan, California, New York, Minnesota, Ohio, Oklahoma, Missouri, Florida, Texas, Washington, and Alabama have each used more than 7 million pounds of "high" explosives during this year and their combined sales represent 63 per cent of the entire sales of this class of explosives.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in October were more than 438,000 kegs, showed that the mills were operated to 58 per cent in October as compared with 49 per cent in September, 45 per cent in August, and 45 per cent in October last year and 43 per cent for the first ten months of 1927. During the first ten months of 1926 the mills were operated to 39 per cent of their capacity. The amount of explosives remaining on hand at the close of October represented 57 per cent of one month's manufacturing capacity of the mills reporting as compared with 40 per cent at the close of October a year ago.

	October, 1926	October, 1927	Jan.-Oct., 1927
Capacity (Kegs)..........	933,583	796,083	7,960,830
Manufactured.............	426,780	464,938	3,451,556
Per cent of capacity......	45	58	43
Shipments................	464,002	456,912	3,397,725
Per cent of capacity......	40	57	43
Sales....................	468,845	438,741	3,511,820
Per cent of capacity......	49	55	42
Stocks, end of month......	376,716	455,570	455,570
Per cent of capacity......	40	57	5.7

The following percentage figures show the extent of capacity to which mills manufacturing black powder were operated in 1924, 1925, 1926, average for ten months in 1926 and in the months of January to October, 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month.

	Manufactured	Shipments	Sales	Stocks
Year 1924..................	41	41	41	3.8
Year 1925..................	38	39	38	3.2
Year 1926..................	40	40	39	3.6
Average, 10 months 1926....	39	39	38	3.9
1927				
January....................	54	55	56	50
February...................	54	47	45	58
March......................	36	36	38	58
April......................	31	32	30	57
May........................	29	36	35	49
June.......................	40	37	33	52
July.......................	37	36	34	53
August.....................	45	45	44	52
September..................	49	45	46	56
October....................	58	57	55	57
Average, 10 months.........	43	43	42	5.7

Reports from 23 mills that sold more than 25 million pounds of permissibles and other high explosives in October showed that the mills were operated to 67 per cent of their capacity in October as compared with 66 per cent in September, 67 per cent in August, 76 per cent in October last year, and 65 per cent average for the first ten months of 1927. During the first ten months of 1926 the mills were operated to 68 per cent of their capacity. The amount of explosives remaining on hand at the close of October represented 16 per cent of one month's manufacturing capacity of the mills reporting, as compared with 19 per cent at the close of October a year ago.

	October, 1926	October, 1927	Jan.-Oct. 1927
Capacity (Pounds)...........	39,528,332	40,945,000	398,700,000
Manufactured................	30,000,558	27,294,602	258,415,407
Per cent of capacity........	76	67	65
Shipments...................	29,351,372	26,837,393	258,617,611
Per cent of capacity........	74	67	65
Sales.......................	27,590,043	25,778,577	248,256,884
Per cent of capacity........	70	63	62
Stocks, end of month........	7,436,278	6,417,799	6,417,799
Per cent of capacity........	19	16	16

The percentage of full-time capacity to which mills manufacturing permissibles and other explosives were operated in 1924, 1925, 1926, average for ten months in 1926, and in the months of January to October, 1927, is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining on hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924	62	62	59	1.4
Year 1925	63	62	59	1.5
Year 1926	68	68	64	1.4
Average, 10 months 1926	68	68	65	1.9
1927				
January	59	58	57	19
February	63	62	57	20
March	64	64	62	20
April	66	69	65	17
May	73	72	63	18
June	65	66	64	17
July	58	58	58	13
August	67	66	63	17
September	66	65	64	15
October	67	66	63	16
Average, 10 months	65	65	63	1.6

PYROTOL: During the first ten months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 14,746,660 pounds of pyrotol of which 2,648,350 pounds represented shipments in October. During the corresponding ten months last year the shipments amounted to 14,261,270 pounds. Most of the pyrotol shipped was for use by farmers in clearing land. Table D shows the amount of pyrotol shipped to each State in October, 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal-mining operations in each State from January to October, 1927, is shown in Table C. Table D shows the quantity of pyrotol distributed in October to the various States.--Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE A - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during October, 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	10,790	649,275	391,200
Alaska	- -	128,300	22,000
Arizona	5,720	169,325	- - -
Arkansas	11,010	281,599	10,500
California	7,546	1,314,365	- - -
Colorado	4,843	410,820	73,300
Connecticut	39	89,650	- - -
Delaware	- -	3,525	- - -
Florida	3,400	498,300	- - -
Georgia	2,579	180,825	- - -
Idaho	811	332,075	- - -
Illinois	117,149	692,675	633,550
Indiana	49,063	364,175	28,250
Iowa	24,844	255,775	1,000
Kansas	25,154	758,335	38,810
Kentucky	56,385	361,685	538,750
Louisiana	- -	362,959	- - -
Maine	82	68,325	- - -
Maryland & D. C.	1,857	135,350	1,750
Massachusetts	91	134,650	- - -
Michigan	510	1,656,500	100
Minnesota	2,883	1,198,100	1,500
Mississippi	49	179,700	- - -
Missouri	12,902	79[illegible],585	3,591
Montana	8,510	433,240	50
Nebraska	115	36,026	- - -
Nevada	2,251	344,650	- - -
New Hampshire	101	33,200	- - -
New Jersey	4	292,850	- - -
New Mexico	50	78,350	26,000
New York	364	1,342,212	9,000
N. Carolina	4,116	444,350	2,500
N. Dakota	3,490	28,450	10,500
Ohio	22,053	834,775	1,650 Rtd.
Oklahoma	14,710	1,014,523	372
Oregon	812	304,250	- - -
Pennsylvania	39,337	3,017,230	2,908,325
Rhode Island	20	14,450	- - -
S. Carolina	635	100,595	- - -
S. Dakota	75	57,100	- - -
Tennessee	13,996	253,950	35,750
Texas	5,758	626,650	26,250
Utah	1,365	639,500	99,350
Vermont	921	73,050	- - -
Virginia	4,461	701,150	130,[illegible]0
Washington	4,360	955,686	45,300
West Virginia	37,386	526,350	1,230,250
Wisconsin	97	277,700	- - -
Wyoming	4,[illegible]7	116,100	105,100
TOTAL OCTOBER 1927	536,565	24,733,145	6,32[illegible],538

3519

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first ten months of 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	93,940	7,031,744	4,099,250
Alaska	371	1,988,300	84,700
Arizona	20,485	1,427,025	- - -
Arkansas	57,591	1,516,446	121,433
California	71,121	15,714,363	2,650
Colorado	48,252	4,442,396	709,150
Connecticut	385	1,282,450	- - -
Delaware	32	64,124	- - -
Florida	25,014	8,016,797	- - -
Georgia	15,422	1,585,300	- - -
Idaho	6,643	3,471,283	8,850
Illinois	505,303	6,639,452	1,935,725
Indiana	392,743	3,539,835	527,175
Iowa	95,169	2,394,025	6,450
Kansas	135,129	6,441,716	226,925
Kentucky	581,146	4,185,265	2,992,100
Louisiana	350	2,794,098	73,300
Maine	1,302	631,975	- - -
Maryland & D. C.	20,985	1,941,100	126,400
Massachusetts	1,370	1,095,825	- - -
Michigan	6,938	17,564,475	1,500
Minnesota	34,901	11,108,577	1,500
Mississippi	2,150	1,245,325	- - -
Missouri	71,215	8,183,982	135,562
Montana	54,157	5,254,717	20,000
Nebraska	1,678	182,776	- - -
Nevada	29,107	2,835,900	200
New Hampshire	443	164,750	- - -
New Jersey	66	2,867,225	- - -
New Mexico	12,746	530,525	257,300
New York	10,718	12,685,636	49,300
N. Carolina	23,353	3,410,625	10,800
N. Dakota	19,077	119,507	22,475
Ohio	216,260	9,696,020	208,500
Oklahoma	97,361	9,409,370	217,755
Oregon	18,607	3,424,025	250
Pennsylvania	839,301	38,942,648	26,321,915
Rhode Island	159	91,400	- - -
S. Carolina	3,337	694,640	- - -
S. Dakota	556	1,065,200	1,300
Tennessee	98,780	3,122,520	284,700
Texas	68,329	7,458,135	65,100
Utah	16,295	6,860,165	751,495
Vermont	3,873	394,500	- - -
Virginia	56,233	3,159,600	1,141,040
Washington	36,339	7,451,433	536,375
West Virginia	443,363	4,764,050	11,777,325
Wisconsin	3,764	4,308,025	50
Wyoming	27,679	1,163,700	776,450
TOTAL 1st 10 MOS. 1927	4,303,661	244,259,850	53,681,100

3519

OCTOBER, 1927

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs	Pounds	Pounds
Quantity used for:			
Coal mining..................	498,097	3,255,550	6,070,063
Metal mining.................	6,835	7,033,800	11,050
Quarrying and nonmetallic mineral mining..............	21,730	6,290,098	27,450
Railway and other construction work......................	20,658	4,610,237	35,775
All other purposes...........	20,995	3,542,460	182,000
TOTAL OCTOBER 1927.............	568,335	24,732,145	6,326,338

JANUARY TO OCTOBER, 1927, INCLUSIVE.

Quantity used for:			
Coal mining..................	3,639,222	28,611,509	51,369,151
Metal mining.................	76,535	73,657,260	120,175
Quarrying and nonmetallic mineral mining..............	204,423	68,283,561	435,070
Railway and other construction work......................	211,453	40,632,323	201,061
All other purposes...........	170,978	33,075,197	1,555,643
TOTAL 1st 10 MOS. 1927.........	4,302,661	244,259,850	53,681,100

TABLE C - Quantity of explosives sold for use in COAL MINES in October 1927 by manufacturers rendering monthly reports.

(Including cumulative figures for the first ten months of 1927).

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama........	9,086	73,983	47,500	506,344	389,100	4,030,350
Arkansas.......	10,783	56,655	4,350	72,200	4,300	19,683
Colorado.......	3,577	34,720	26,350	189,075	71,500	660,900
Illinois.......	116,000	438,630	67,275	377,725	613.350	1,809,900
Indiana........	46,937	390,765	141,950	852,500	12,050	473,050
Iowa...........	23,753	91,037	54,075	133,400	1,000	5,000
Kansas.........	24,137	147,330	92,625	587,576	42,360	224,825
Kentucky.......	53,457	550,591	71,100	817,700	369,850	2,763,380
Maryland.......	1,600	16,926	- -	41,000	350	71,700
Michigan.......	- -	4,227	4,450	44,950	100	100
Missouri.......	10,131	50,963	25,900	148,450	13,131	43,712
Montana........	6,428	40,528	200	13,400	- -	9,950
New Mexico.....	- -	3,705	- -	20,600	26,000	245,050
North Dakota...	5,456	18,676	11,525	68,000	500	12,475
Ohio...........	18,462	182,629	20,800	349,500	2,400Rtd	53,450
Oklahoma.......	13,633	87,336	32,100	129,500	16,722	187,296
Penna.(Bitum.).	38,334	297,156	86,250	1,097,858	1,120,875	10,556,370
Tennessee......	12,453	83,164	17,050	140,350	35,550	206,200
Texas..........	1,932	20,055	- -	5,700	- -	- -
Utah...........	- -	- -	250	35,550	94,350	730,495
Virginia.......	2,915	44,557	34,600	311,850	179,400	1,127,090
Washington.....	1,398	11,300	5,500	66,800	10,100	334,350
West Virginia..	34,692	420,670	75,325	857,875	1,219,450	11,408,575
Wyoming........	4,260	17,531	2,700	43,050	88,100	656,500
Other States...	1,621	9,286	1,700	83,175	24,550	101,900
Total (Bitum)..	441,643	3,153,113	822,225	6,894,728	4,330,338	35,823,201
Penna. (Anth)..	56,454	486,109	2,433,325	21,716,781	1,739,725	15,545,950
Grand Total as reported....	498,097	3,639,222	3,255,550	28,611,509	6,070,063	51,369,151

Est. total inc. non-reporting companies	) Anth.	496,100	23,111,000	15,569,000
	) Bitum.	3,217,300	7,331,000	35,374,000
Total reported plus estimate..		3,713,400	30,442,000	51,443,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period October 1, 1927 to October 31, 1927.

State	State Highway Department Roads	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
Alabama...............	2,000	20,000	-	-	22,000
California...........	-	-	65,000	-	65,000
Georgia..............	-	40,000	2,000	-	42,000
Idaho.................	-	21,200	35,000	-	56,200
Kansas................	44,000	-	-	-	44,000
Louisiana............	-	20,000	-	30,000	50,000
Michigan.............	-	164,000	-	-	164,000
Minnesota............	500	159,000	8,000	8,000	175,500
Missouri.............	-	18,000	-	-	18,000
Montana..............	4,000	49,850	-	-	53,850
New Mexico...........	-	-	31,000	-	31,000
North Carolina........	16,500	238,400	-	-	254,900
Oregon................	57,200	331,350	-	-	388,550
South Carolina........	2,500	147,250	-	-	149,750
Tennessee............	2,000	-	-	-	2,000
Virginia.............	25,000	-	-	-	25,000
Washington...........	52,000	459,900	-	22,000	533,900
Wisconsin............	-	569,900	-	-	569,900
Wyoming..............	-	-	3,300	-	3,300
Total October.........	205,700	2,238,850	144,300	60,000	2,648,850
Total September.......	125,000	1,450,550	24,000	70,300	1,669,850
Total August.........	199,500	220,250	336,400	24,000	780,150
Total July...........	140,850	444,000	122,000	20,000	726,850
Total June...........	225,300	685,250	108.300	72,900	1,091,750
Total May............	162,000	825,500	26,000	352,100	1,365,600
Total April..........	281,550	1,669,550	7,500	222,000	2,180,600
Total March..........	249,500	1,916,860	-	108,700	2,275,060
Total February.......	170,750	1,020,150	-	-	1,190,900
Total January........	93,000	704,050	-	20,000	817,050
Grand Total..........	1,853,150	11,175,010	768,500	950,000	14,746,560

622.09
Un 32 mo
cop. 2

Serial No. 2843,
December, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

THE LIBRARY OF THE
JUL 2
UNIVERSITY OF ILLINOIS

THE SULPHUR CONTENT OF COMMERCIAL MOTOR FUELS

By A. J. Kraemer[1], F. C. Lane[2] and C. S. Luce[3]

Introduction

A great deal of interest has been manifested in the question of sulphur in fuels for automobile engines. Many different opinions have been expressed with respect to the effect of sulphur in gasoline on engine wear and engine performance. A wide difference of opinion exists as to the permissible limit of sulphur content for satisfactory operation.

One of the duties of the Technical Committee on Lubricants and Liquid Fuels of the Federal Specifications Board is to recommend to the Board, the maximum permissible content of sulphur for motor fuels for the use of Government agencies. The Technical Committee has recommended, and the Federal Specifications Board has concurred in the recommendation, that 0.10 percent of sulphur is a satisfactory limit, in view of all of the technologic and economic factors[4]. The contention has been made that a large quantity of gasoline containing more than 0.10 percent of sulphur is being sold in the United States, and that this gasoline is being sold without complaints from users on the score of excessive sulphur. It has been maintained that the Federal Specifications Board should raise the limit for sulphur content of motor fuels, in order to relieve some refiners of the necessity of destroying a portion of their potential production of motor fuel, in the process of removing sulphur in excess of 0.10 percent. The Technical Committee has maintained that no hardship would accrue to the Government by keeping the upper limit for sulphur at 0.10 percent.

In keeping informed on the sulphur content of motor fuels sold throughout the United States, the Bureau of Mines has made analyses of the samples that were collected in making the semi-annual gasoline survey during July, 1927. The results of the gravity and distillation tests of the survey were published as Serial

---

[1] Associate petroleum chemist, Bureau of Mines, Department of Commerce.

[2] Assistant petroleum chemist, Bureau of Mines.

[3] Junior chemist, Bureau of Mines.

[4] Federal Specifications Board, Standard Specification Number 2d, United States Government master specification for lubricants and liquid fuels, and methods for sampling and testing. Technical Paper 323B, Bureau of Mines, obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents.

No. 2827[5]. In the present report, results are reported of tests for color by the Saybolt chromometer, doctor test, corrosion test, and sulphur by the lamp method. These tests are described in detail in Technical Paper 323B[4]. The numbering of samples is the same in this report as in Serial No. 2827; for example, Number 25 of this report is the same sample as Number 25 of Serial No. 2827.

The detailed results of the examination of the motor fuels is given in Table I, showing physical and chemical data for samples from different cities. In Table 2, the results for sulphur content are tabulated so as to show distribution of the samples, according to sulphur content.

Discussion of Results

Sulphur. - The most striking feature of the results presented in this report is that they indicate that the motor fuels now being sold in the United States contain small proportions of sulphur. The United States Government specifications for motor fuels permit a content of 0.10 percent sulphur, and there are only seven samples out of 130 (5.4 percent) included in this report, that contained more than this quantity of sulphur. (No result was reported for sample No. 40, from Pittsburgh). Five samples, or 3.8 percent had exactly 0.10 percent of sulphur. It is apparent from the gravity as given in Serial No. 2827[5] that half of the twelve samples that contained as much as 0.10 percent of sulphur, were benzol blends. It is highly improbable that the seven samples that exceeded the specification limit for sulphur, represented as much as 5.4 percent of the total volume of gasoline represented by the 130 samples for which results are given.

Doctor Test. - Twenty-seven samples, or 20.6 percent of the total number, were positive to the doctor test. Only three of the positive doctor test samples were among the twelve high-sulphur samples, indicating that the doctor test is not a criterion of sulphur content.

Corrosion Test. - Only two samples are reported as showing discoloration, and both of these are among the high sulphur samples. The interpretation of the results of the corrosion test is dependent upon the judgment of the tester, and considerable difference of opinion is frequently encountered in the interpretation of the results of the test.

Conclusion. - The most important conclusion to be drawn from the results presented in this report is that the sulphur content of more than ninety percent of the gasoline represented by these samples, is less than 0.10 percent. It is shown that the doctor test is of no importance, as a criterion either of sulphur content, or of tendency to corrode copper, but this has been realized by refiners for several years, and is merely confirmed by these results.

---

[5] Lane, E. C., Condit, D. J., and Luce, C. S. Sixteenth semi-annual motor gasoline survey. Reports of Investigations, Serial No. 2827, Bureau of Mines, August, 1927.

TABLE 1 -- Physical and chemical data for samples of motor gasoline from different cities.

Motor Gasoline Survey, JULY, 1927.

Sample Number	Color Saybolt	Doctor Test	Corrosion Test	Sulphur Per cent.
		NEW YORK		
1	6	Negative	No	.05
2	+25	Positive	No	.02
3	21	Negative	No	.02
4	24	Positive	No	.05
5	11	Negative	No	.05
6	17	do	No	.05
7	24	Positive	No	.05
8	Colored[6]	Negative	No	.02
9	21	do	No	.02
10	18	do	No	.05
11	22	do	No	.02
12	23	do	No	.13
		WASHINGTON		
13	Colored	Negative	No	.06
14	22	Positive	No	.10
15	21	Negative	No	.06
16	21	Positive	No	.06
17	23	do	No	.09
18	25	do	No	.08
19	Colored	Negative	No	.04
20	19	do	No	.03
21	Colored	do	No	.02
22	18	Positive	No	.13
23	+25	Negative	No	.05
24	23	Positive	No	.05
25	24	do	No	.10
26	Colored	Negative	No	.05
27	21	do	No	.04
28	21	do	No	.12
29	Colored	do	No	.08
30	20	do	No	.06

---

[6] "Colored" denotes that the gasoline as marketed is artificially colored.

TABLE 1 -- Physical and chemical data for samples of motor gasoline from different cities. (Continued).

Sample Number	Color Saybolt	Doctor Test	Corrosion Test	Sulphur Per cent
		PITTSBURGH		
31	Colored	Negative	No	.04
32	+25	Positive	No	.03
33	23	do	No	.04
34	21	Negative	No	.10
35	18	do	No	.03
36	Colored	do	No	.02
37	20	do	No	.07
38	12	do	No	.10
39	22	do	No.	.06
40	Colored	do	No	--
41	22	do	No	.07
42	Colored	do	No	.09
43	+25	do	No	.04
44	Colored	Positive	No	.02
45	24	Negative	No	.08
46	+25	Positive	No	.04
		CHICAGO		
47	+25	Negative	No	.04
48	23	do	No	.03
49	21	do	No,	.02
50	23	do	No	.02
51	23	do	No	.04
52	19	do	No	.09
53	13	do	No	.04
54	25	do	No	.03
55	+25	do	No	.02
56	15	do	No	.03
57	24	do	No	.05
58	23	do	No	.03
59	+25	do	No	.03
60	21	do	No	.04
61	21	Positive	No	.04
62	19	do	No	.04
63	25	do	No	.02
64	25	do	No	.03

TABLE 1 -- Physical and chemical data for samples of motor gasoline from different cities (Continued).

Sample Number	Color Saybolt	Doctor Test	Corrosion Test	Sulphur Per cent
		NEW ORLEANS		
65	22	Positive	No	.05
66	Colored	Negative	No	.06
67	21	do	No	.07
68	18	do	No	.05
69	Colored	do	No	.04
70	23	do	No	.09
71	23	Positive	No	.05
72	21	Negative	No	.21
73	23	do	No	.03
74	17	do	No	.17
		ST. LOUIS		
75	17	Negative	No	.03
76	23	Positive	No	.09
77	22	Negative	No	.05
78	24	do	No	.03
79	19	do	Yes	.25
80	19	do	No	.06
81	16	Positive	No	.06
82	21	Negative	No	.02
83	+25	do	No	.03
84	22	do	Yes	.23
85	+25	do	No	.02
86	+25	do	No	.02
87	+25	Positive	No	.05
88	25	Negative	No	.06
89	+25	do	No	.05
90	+25	do	No	.04
91	23	Positive	No	.03
92	21	Negative	No	.07
93	+25	Positive	No	.05
94	25	Negative	No	.05
95	25	do	No	.06

TABLE 1 -- Physical and chemical data for samples of motor gasoline from different cities (Continued).

Sample Number	Color Saybolt	Doctor Test	Corrosion Test	Sulphur Per cent
		BARTLESVILLE		
96	+25	Negative	No	.02
97	+25	Positive	No	.02
98	Colored	Negative	No	.05
99	+25	do	No	.04
100	+25	do	No	.03
101	+25	do	No	.03
102	22	do	No	.03
103	25	do	No	.05
104	24	do	No	.03
105	+25	do	No	.02
106	22	do	No	.03
107	- 9	do	No	.02
		DENVER		
108	21	Negative	No	.02
109	23	Positive	No	.05
110	23	Negative	No	.03
111	15	do	No	.05
112	22	do	No	.01
113	18	do	No	.02

TABLE 1 -- Physical and chemical data for samples of motor gasoline from different cities (Continued).

Sample Number	Color Saybolt	Doctor Test	Corrosion Test	Sulphur Per cent
		LARAMIE		
114	13	Negative	No	.05
115	15	do	No	.06
116	15	do	No	.06
117	16	do	No	.07
118	15	do	No	.07
119	- 9	do	No	.03
		SAN FRANCISCO		
120	+25	Negative	No	.05
121	+25	do	No	.04
122	+25	do	No	.07
123	24	do	No	.09
124	25	do	No	.07
125	+25	do	No	.07
126	+25	do	No	.05
127	Colored	do	No	.10
128	+25	do	No	.04
129	19	do	No	.08
130	+25	do	No	.07
131	21	do	No	.04

"Colored" denotes that the gasoline as marketed is artificially colored.

TABLE 2 -- Showing distribution of samples according to sulphur content

City	Sulphur, per cent .01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.12	.13	.17	.21	.23	Total
New York	-	5	-	-	6	-	-	-	-	-	-	1	-	-	-	12
Washington	-	1	1	2	3	4	-	2	1	2	1	1	-	-	-	18
Pittsburgh	-	2	2	4	-	1	2	1	1	2	-	-	-	-	-	15
Chicago	-	4	6	6	1	-	-	-	1	-	-	-	-	-	-	18
New Orleans	-	-	1	2	3	1	1	-	1	-	-	-	1	1	-	11
St. Louis	-	3	4	-	5	4	1	-	1	-	-	-	-	-	2	20
Bartlesville	-	4	6	1	1	-	-	-	-	-	-	-	-	-	-	12
Denver	1	2	1	-	2	-	-	-	-	-	-	-	-	-	-	6
Laramie	-	-	1	-	1	2	2	-	-	-	-	-	-	-	-	6
San Francisco	-	-	-	3	2	-	4	1	1	1	-	-	-	-	-	12
Total	1	21	22	18	24	12	10	4	6	5	1	2	1	1	2	130

622.09
Un32mo
cop.2

Serial No. 2844.
December, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

COAL-MINE FATALITIES IN NOVEMBER, 1927

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

By W. W. Adams[1]

Coal-mine fatalities in the United States in November 1927 numbered 159 according to information furnished by State mine inspectors to the Bureau of Mines, Department of Commerce. Thirty-eight of the fatalities occurred in the anthracite mines of Pennsylvania; the remaining 121 were at bituminous mines throughout the country. The fatality rate for the month was 3.35 per million tons, as compared with 3.39 for the same month last year. The production of bituminous coal during November was 4[illegible],[illegible]28,000 tons, giving a fatality rate for this branch of the industry of 3.0[illegible] per million tons, as against 3.07 for the corresponding month a year ago. Reports from the anthracite industry showed 6,90[illegible],000 tons of coal mined, 38 fatalities, and a rate of 5.51 per million tons; the rate for November last year was 5.95.

For the eleven-month period, January to November of the present year, a loss of 2,002 lives in the coal-mining industry has been recorded, which is 262 less than for the same period last year. It is probable that final returns will increase this number slightly, but the eleven-month death rate, based upon reports to date, is 3.62 as compared with 3.[illegible]2 for the eleven-month period of 1926. Of the fatalities thus far reported, 1,551 were at bituminous mines and 451 at anthracite mines. The fatality rates per million tons were 3.24 for bituminous mines and 6.04 for anthracite mines, based on a production of 478,527,000 tons of bituminous coal and 74,632,000 tons of anthracite.

There were no major disasters during November - that is, no disasters causing the death of five or more men - but there is a record of eight such disasters for previous months of the current year, with a resulting loss of 155 lives. This record is a great improvement over the same period of 1926, which showed 15 major disasters which caused the death of 311 men. The fatality rate based exclusively on major disasters was 0.280 for the eleven-month period of 1927 and 0.524 for the first eleven months of 1926.

An analysis of the 2,002 fatalities during the eleven months of the present year shows a reduction in the death rate per million tons of coal for haulage accidents and for gas and dust explosions, and a slight increase for explosives and electricity. No change occurred in the rate for falls of roof and coal. The comparative rates for these principal causes of accidents were:

---

[1] Statistician, Bureau of Mines, Department of Commerce.

	Year 1926	Jan.-Nov. 1926	Jan.-Nov. 1927
All causes	3.839	3.817	3.510
Falls of roof and coal	1.940	1.836	1.571
Haulage	.558	.664	.564
Gas or dust explosions	.642	.659	.407
Explosives	.147	.140	.193
Electricity	.140	.146	.177

Tables 1 to 4 inclusive, present a detailed statistical comparison of the number and causes of accidents and corresponding rates in 1927 with similar figures for earlier years.--Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE 1. - NUMBER OF DEATHS PER MILLION TONS OF COAL PRODUCED AT ALL MINES IN THE UNITED STATES
(Includes both anthracite and bituminous coal)

	Year 1926	Jan.-Nov. 1926	Jan.-Nov. 1927
Falls of Roof & Coal	1.946	1.936	1.831
At face	1.399	1.403	1.361
In room	.240	.327	.239
On entry	.195	.192	.217
On slope	.012	.014	.015
Haulage	.658	.664	.564
Switching and spragging	.020	.018	.011
Coupling	.009	.007	.020
Falling from trips	.030	.029	.034
Run over	.243	.246	.219
Caught between car and rib	.138	.143	.150
Caught between car and roof	.029	.027	.032
Runaway cars	.058	.057	.051
Miscellaneous	.132	.137	.047
Gas or Dust Explosions	.643	.639	.407
Open light	.193	.148	.076
Defective safety lamp	.005	.005	.002
Electric arc	.082	.088	.051
Shot	.077	.086	.025
Powder explosion	.005	.005	.005
Miscellaneous	.280	.307	.248
Explosives	.148	.140	.192
Transportation	- -	- -	.002
Charging	.006	.007	.009
Suffocation	.008	.003	.002
Drilling into old holes	.003	.003	.004
Striking in loose rock	- -	- -	- -
Thawing	- -	- -	- -
Caps & detonators	.001	.002	.009
Unguarded shots	.006	.007	.005
Returned too soon	.014	.014	.015
Premature shot	.049	.047	.072
Sparks from lamp, etc.	.006	.005	.007
Delayed shots	.015	.014	.015
Shot breaking through rib	.011	.008	.016
Miscellaneous	.029	.030	.036
Electricity	.146	.146	.177
Direct contact with trolley wire	.052	.051	.078
Tools striking trolley wire	.003	.003	.004
Contact with mining machine	.014	.010	.016
Contact with machine feed wire	.009	.008	.025
Contact with haulage motor	.003	.003	.002
Miscellaneous	.065	.071	.052

TABLE 2 - COAL-MINE FATALITIES DURING NOVEMBER, 1927, BY CAUSES AND STATES

CAUSE	Ala	Alas	Ark	Col	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
UNDERGROUND																													
Falls of roof..............	3	-	-	3	3	3	2	-	4	-	-	1	-	-	-	4	2	18	-	-	-	-	1	-	20	1	65	14	79
Falls of side..............	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	1	-	4	9	13
Haulage....................	2	-	-	1	1	1	1	-	1	-	-	-	1	-	-	-	-	6	-	-	-	-	2	-	4	-	20	7	27
Gas or dust explosions.....	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	3	-	3
Explosives.................	-	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-	-	1	-	-	-	1	-	1	2	-	8	4	12
Suffocated by mines gases..	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Electricity................	2	-	-	-	1	-	-	-	2	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	7	-	7
Animals....................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mining machines............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mine fires.................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other causes...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	3	-	3
TOTAL..........	8	-	-	5	5	5	3	-	9	-	1	1	1	1	-	4	3	29	-	-	-	1	3	1	27	3	110	35	145
SHAFT																													
Persons falling............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Objects falling............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cages, skips...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1
Other causes...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL..........	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	2
SURFACE																													
Mine cars..................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	3	-	3
Electricity................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Machinery..................	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1
Boiler explosions..........	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Railway cars...............	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	1
Other causes...............	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	4	1	5
TOTAL..........	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	4	1	10	2	12
GRAND TOTAL, Nov., 1927....	9	0	0	5	6	5	3	0	9	0	1	1	1	1	0	4	4	31	0	0	0	1	3	1	32	4	121	38	159
GRAND TOTAL, Nov., 1926....	9	0	0	4	18	3	5	2	15	0	0	3	1	0	0	6	3	45	0	3	0	2	7	3	50	1	182	44	226 a/

a/ Includes 2 fatalities in Ga. & N. C.

TABLE 3 - COAL-MINE FATALITIES DURING 1927 AND 1926, BY MONTHS AND STATES.

	Ala	Alas	Ark	Col	Ga. & N.C.	Ill	Ind	Ia	Kan	Ky	Md	Mch	Mo	Mnt	NMx	NDk	O	Ok	Pa bit	SDk	Tenn	Tex	Ut	Va	Wsh	WVa	Wyo	TOTAL BITUM	Pa anth	GRAND TOTAL
January..............	6	-	2	8	-	19	3	1	-	23	-	1	1	1	2	-	7	2	36	-	3	-	1	2	1	43	4	166	46	212
February..............	7	-	2	5	-	11	7	1	2	10	-	-	-	1	2	2	10	2	31	-	-	-	5	5	2	35	-	140	41	181
March..............	6	-	-	7	-	23	7	1	2	6	-	-	-	-	2	-	6	2	35	-	3	-	2	3	1	38	1	145	42	187
April..............	6	-	-	2	-	4	-	2	-	2	-	1	-	1	-	-	4	2	33	-	1	-	3	3	7	144	-	215	42	257
May..............	6	-	1	8	-	4	-	1	-	11	-	-	-	-	1	-	5	1	26	-	-	-	3	9	2	50	1	129	53	182
June..............	4	-	1	3	-	-	2	-	1	5	1	-	-	2	3	-	3	2	29	-	-	-	2	1	1	53	2	115	54	169
July..............	11	-	1	1	-	-	1	-	1	17	1	-	-	-	-	-	6	3	25	-	3	-	1	-	1	35	1	108	30	138
August..............	9	-	1	4	-	2	1	2	1	30	-	-	-	1	2	-	3	-	34	-	3	-	1	5	1	38	5	143	26	169
September..............	6	-	-	4	-	3	4	-	2	16	1	-	1	1	2	-	5	3	31	-	1	2	1	4	1	38	2	128	38	166
October..............	14	-	-	2	-	11	4	2	1	8	1	-	3	3	2	-	2	5	22	-	3	-	2	5	2	48	1	141	41	182
November..............	9	-	-	5	-	6	5	3	-	9	-	1	1	1	1	-	4	4	31	-	-	-	1	3	1	32	4	121	38	159
Total, 11 months, 1927.	84	0	8	49	0	83	34	13	10	137	4	3	6	11	17	2	55	26	333	0	17	2	22	40	20	554	21	1,551	451	2,002
Total, 11 months, 1926.	129	1	5	44	3	138	37	13	16	164	12	1	9	4	12	1	70	124	385	0	48	0	19	53	10	538	20	1,856	407	2,263
Total, 1926....	139	1	7	53	3	166	78	16	17	178	12	1	9	5	13	1	80	124	420	0	50	0	20	58	15	573	22	2,061	453	2,514

TABLE 4 - AVERAGE NUMBER OF MEN KILLED PER MILLION TONS OF COAL PRODUCED

Cause of accident	Per cent of total 1917-1926	Death rates per million short tons						
		Average for 10 years 1917-1926	Year 1925	Year 1926	Average for Nov. 10 years 1917-1926	1927		1926
						Oct.	Nov.	Nov.
Bituminous Mines								
1. Falls of roof and coal	43.95	1.759	1.750	1.734	1.740	2.000	1.698	1.723
2. Underground haulage.	18.19	.653	.586	.665	.609	.568	.492	.642
3. Explosions of gas or coal dust:								
Local explosions	2.50	.104	.112	.080	.095	.091	.074	.101
Major explosions	11.25	.390	.469	.570	.542	- - -	- - -	.084
4. Explosives	3.30	.118	.094	.082	.108	.023	.197	.068
5. Electricity	4.02	.144	.154	.164	.102	.182	- - -	.118
6. Mining machines.	1.33	.048	.067	.045	.050	.068	.172	.017
7. Other causes underground . . .	2.93	.105	.089	.068	.081	.068	.074	.017
8. All causes underground	92.47	3.321	3.321	3.408	3.327	3.000	2.707	2.770
9. All shaft accidents.	1.72	.062	.058	.047	.072	.091	.025	.068
10. All accidents on surface . . .	5.81	.209	.148	.148	.201	.114	.246	.236
11. All accidents.	100.00	3.592	3.527	3.603	3.600	3.205	2.978	3.074
Anthracite Mines								
1. Falls of roof and coal	42.71	2.496	2.750	2.605	2.449	2.025	3.332	2.433
2. Underground haulage.	12.75	.745	.906	.616	.557	.540	1.014	.541
3. Explosions of gas:								
Local explosions	6.71	.392	.421	.331	.498	.946	- - -	.135
Major explosions	1.51	.088	.275	.249	- - -	- - -	- - -	- - -
4. Explosives	12.37	.723	.357	.532	.763	.946	.580	1.217
5. Electricity.	1.00	.059	.065	.024	.015	.135	- - -	- - -
6. Other causes underground . . .	8.18	.478	.323	.462	.411	.405	.145	.946
7. All causes underground	85.23	4.981	5.597	4.879	4.693	4.997	5.071	5.272
8. All shaft accidents.	2.30	.134	.065	.095	.118	- - -	.145	.135
9. All accidents on surface . . .	12.47	.729	.809	.391	.645	.540	.290	.541
10. All accidents.	100.00	5.844	6.471	5.365	5.456	5.537	5.506	5.948

3650

622.09
Un 32 mo
cop. 2

Serial No. 2845
December, 1927

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

CONSUMPTION OF EXPLOSIVES IN NOVEMBER, 1927

By W. W. Adams[1]

The quantity of explosives sold for domestic consumption in the United States during November 1927 was 471,100 kegs (11,777,500 pounds) of black blasting powder, 5,460,000 pounds of permissible explosives, and 23,185,000 pounds of high explosives other than permissibles. The above figures are based on reports from manufacturers to the Bureau of Mines, Department of Commerce, and include an estimate of sales by several companies that do not furnish monthly reports. Statements actually received from the reporting manufacturers showed sales of 461,656 kegs of black powder, 5,452,061 pounds of permissibles, and 21,765,560 pounds of other high explosives. All three classes of explosives showed reductions in quantities sold in November 1927 as compared with November 1926. The reductions amounted to 34 per cent for black blasting powder, 21 per cent for permissibles, and 7 per cent for high explosives other than permissibles.

PERMISSIBLE EXPLOSIVES: Sales of permissible explosives in November brought the total sales during the eleven-month period of January to November to 59,221,000 pounds, including 59,133,161 pounds actually reported and an estimate to cover sales by several non-reporting companies. The quantity sold in the eleven-month period was 3 per cent less than that sold during the same period in 1926. More than 95 per cent of the explosives were for use in coal mines, 66 per cent being for bituminous mines and 29 per cent for anthracite mines. The quantity used at bituminous mines during the eleven months, January to November, has averaged 82 pounds of permissibles, or 29 per cent of the 286 pounds of all kinds of explosives per thousand tons of bituminous coal produced. The record for anthracite mines shows 759 pounds of all kinds of explosives per thousand tons of coal produced, of which 232 pounds, or 31 per cent, were permissibles. The large coal-producing States of Pennsylvania, West Virginia, Alabama, Kentucky, Illinois, and Virginia used 90 per cent of the entire amount of this class of explosives.

BLACK BLASTING POWDER: The amount of black blasting powder sold during the period January to November 1927 was 4,861,400 kegs including 4,764,317 kegs sold by reporting companies and an estimate of sales by non-reporting companies. There was a decrease of 15 per cent in the sales for this period in 1927 as compared with the same eleven-month period in 1926. Eighty-five per cent of the total quantity was sold for use in coal mines, 74 per cent being for bituminous mines and 11 per cent for anthracite mines. The quarrying and non-metallic mining industry used more than 4 per cent, while 5 per cent was used in railway work. Metal mining

---

[1] - Statistician, Bureau of Mines, Department of Commerce.

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

and miscellaneous purposes used 6 per cent. In the coal-mining industry, the consumption of black blasting powder at bituminous mines since January first has averaged 187 pounds, or 65 per cent, of a total of 286 pounds of all kinds of explosives per thousand tons of coal produced while in the anthracite mines the average consumption of black powder was 184 pounds, or 24 per cent, of the 759 pounds of all classes of explosives used for each thousand tons of coal produced. States using the largest amounts of this class of explosives during the past eleven months are Pennsylvania, Kentucky, Illinois, West Virginia, Indiana and Ohio. These six States received 69 per cent of the entire volume of sales during the eleven-month period, January to November, 1927.

OTHER HIGH EXPLOSIVES: Sales of high explosives other than permissibles brought the total sales of this class of explosives during the first eleven months of 1927 to 283,126,000 pounds, a decrease of 2 per cent in comparison with the quantity sold during the same period in 1926. Sales during 1927 include 266,025,410 pounds actually reported to the Bureau of Mines and an estimate of sales by several companies that do not furnish monthly reports. Metal mining was the largest consumer of this class of explosives during the eleven-month period, the consumption amounting to 30 per cent of the total quantity sold. Quarrying and nonmetallic mineral mining used 27 per cent; coal mining used 12 per cent (9 per cent by anthracite mines and 3 per cent by bituminous mines); and railway and other construction work 17 per cent. The remaining 14 per cent was used for miscellaneous purposes. The amount used at anthracite mines since January first has averaged 343 pounds per thousand tons of coal produced, or 45 per cent of the 759 pounds of all kinds of explosives per thousand tons. The corresponding eleven-months' consumption at bituminous coal mines was 17 pounds of high explosives, or 6 per cent of the 286 pounds of all kinds of explosives used per thousand tons of coal produced. The following States have used more than seven million pounds of "high" explosives during the past eleven months: Pennsylvania, Michigan, California, New York, Minnesota, Ohio, Oklahoma, Florida, Missouri, Texas, Washington, Alabama, Utah, Illinois, and Kansas. The combined sales to these States represent 71 per cent of the entire sales of this class of explosives.

CAPACITY OF MILLS: Reports covering 25 mills whose aggregate sales of black blasting powder in November were more than 360,000 kegs, showed that the mills were operated to 48 per cent in November as compared with 58 per cent in October, 49 per cent in September, 52 per cent in November last year and 44 per cent for the first eleven months of 1927. During the first eleven months of 1926 the mills were operated to 40 per cent of their capacity. The amount of explosives remaining on hand at the close of November represented 57 per cent of one month's manufacturing capacity of the mills reporting as compared with 38 per cent at the close of November a year ago.

	November, 1926	November, 1927	Jan.-Nov. 1927
Capacity (Kegs)	953,583	796,083	8,756,913
Manufactured	494,398	378,544	3,830,100
Per cent of capacity	52	48	44
Shipments	508,124	383,963	3,781,658
Per cent of capacity	53	48	43
Sales	492,883	360,229	3,672,049
Per cent of capacity	52	45	42
Stocks, end of month	361,974	450,195	450,195
Per cent of capacity	38	57	5.1

The following percentage figures show the extent of capacity to which mills manufacturing black powder were operated in 1924, 1925, 1926, average for eleven months in 1926 and in the months of January to November, 1927, and the percentage of manufacturing capacity represented by shipments, sales, and stocks on hand at the close of each month.

	Manufactured	Shipments	Sales	Stocks
Year 1924	41	41	41	3.8
Year 1925	38	39	38	3.2
Year 1926	40	40	39	3.6
Average, 11 months 1926.	40	40	39	3.5
1927				
January	54	55	56	50
February	54	47	45	58
March	36	36	38	53
April	31	32	30	57
May	39	36	35	49
June	40	37	33	52
July	37	36	34	53
August	45	45	44	53
September	49	45	46	56
October	58	57	55	57
November	48	48	45	57
Average, 11 months	44	43	42	5.1

Reports from 23 mills that sold more than 23 million pounds of permissibles and other high explosives in November showed that the mills were operated to 62 per cent of their capacity in November as compared with 67 per cent in October, 66 per cent in September, 69 per cent in November last year, and 65 per cent average for the first eleven months of 1927. During the first eleven months of 1926 the mills were operated to 65 per cent of their capacity. The amount of explosives remaining on hand at the close of November represented 16 per cent of one month's manufacturing capacity of the mills reporting, as compared with 15 per cent at the close of November a year ago.

	November, 1926	November, 1927	Jan.-Nov. 1927
Capacity (pounds)...	39,528,332	40,945,000	439,645,000
Manufactured	27,267,851	25,231,150	283,646,557
Per cent of capacity	69	62	65
Shipments	28,771,429	25,045,993	288,663,304
Per cent of capacity	73	61	65
Sales	25,590,692	23,105,095	271,342,509
Per cent of capacity	65	56	62
Stocks, end of month	6,076,420	6,592,192	6,592,192
Per cent of capacity	15	16	1.5

The percentage of full-time capacity to which mills manufacturing permissibles and other explosives were operated in 1924, 1925, 1926, average for eleven months in 1926, and in the months of January to November, 1927, is shown by the following figures; also the ratio between the amount of explosives sold, shipped, or remaining on hand at the close of each month and the total manufacturing capacity of the mills.

	Manufactured	Shipments	Sales	Stocks
Year 1924	62	62	59	1.4
Year 1925	62	62	59	1.5
Year 1926	68	68	64	1.4
Average, 11 months 1926.	69	69	65	1.4
1927				
January	59	58	57	19
February	63	62	57	20
March	64	64	62	20
April	66	69	65	17
May	73	72	69	18
June	65	66	64	17
July	58	58	58	15
August	67	66	63	17
September	66	68	64	15
October	67	66	63	16
November	62	61	56	16
Average, 11 months	65	65	62	1.5

PYROTOL: During the first eleven months of 1927 the Department of Agriculture, through the Bureau of Public Roads, distributed 16,382,210 pounds of pyrotol of which 1,935,550 pounds represented shipments in November. During the corresponding eleven months last year the shipments amounted to 15,043,100 pounds. Most of the pyrotol shipped was for use by farmers in clearing land. Table D shows the amount of pyrotol shipped to each State in November, 1927, and the general purpose for which the explosives were used.

STATISTICAL TABLES: Tables A and B show the quantity of explosives shipped to each State and total sales for the United States segregated to show the amount consumed by industries. The quantity of explosives reported sold for use in coal-mining operations in each State from January to November, 1927 is shown in Table C. Table D shows the quantity of pyrotol distributed in November to the various States.--Reports of Investigations, Bureau of Mines, Department of Commerce.

TABLE A - Amount of Explosives (excluding exports) manufactured in the United States and used in the various States during November, 1927.

State	Black blasting powder		High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)		Pounds	Pounds
Alabama	6,295		673,775	416,600
Alaska	-		225,000	-
Arizona	1,540		72,960	-
Arkansas	7,573		283,303	27,300
California	4,580		1,294,045	2,600
Colorado	4,126		455,930	62,300
Connecticut	20		96,550	-
Delaware	-		6,150	-
Florida	1,325		647,200	-
Georgia	2,220		131,425	-
Idaho	350		284,200	-
Illinois	79,355		531,331	373,950
Indiana	48,968		284,230	79,375
Iowa	16,261		251,000	1,000
Kansas	24,009		639,108	50,345
Kentucky	37,733		376,270	231,400
Louisiana	-		302,340	24,450
Maine	54		44,435	-
Maryland & D. C.	1,642		119,100	11,500
Massachusetts	61		104,800	-
Michigan	10	Rtd.	1,649,175	1,000
Minnesota	941		302,775	1,500Rtd.
Mississippi	839		206,650	-
Missouri	14,423		743,000	8,350
Montana	8,379		493,437	3,000
Nebraska	93		25,125	-
Nevada	1,435		315,625	-
New Hampshire	49		13,075	-
New Jersey	3		268,850	-
New Mexico	560		41,500	48,000
New York	1,513		903,835	5,300
N. Carolina	2,153		208,175	1,500
N. Dakota	6,745		29,600	6,500
Ohio	21,783		587,066	2,500
Oklahoma	13,818		604,465	44,366
Oregon	650		210,415	-
Pennsylvania	31,121		3,773,533	2,725,675
Rhode Island	23		13,230	-
S. Carolina	509		69,000	-
S. Dakota	101		93,705	500
Tennessee	9,141		282,300	11,250
Texas	5,752		946,295	-
Utah	580		633,100	66,500
Vermont	7		9,650	-
Virginia	6,015		266,300	52,150
Washington	6,021		626,845	86,650
West Virginia	35,267		419,250	974,200
Wisconsin	363		275,375	-
Wyoming	6,798		121,200	135,400
TOTAL NOVEMBER 1927	461,656		21,765,560	5,452,061

3367

TABLE B - Amount of explosives (excluding exports) manufactured in the United States and used in the various States during the first eleven months of 1927.

State	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Alabama	100,235	7,708,513	4,506,850
Alaska	371	2,213,390	84,700
Arizona	22,025	1,499,985	-
Arkansas	65,164	1,799,749	148,733
California	75,701	17,008,708	4,650
Colorado	52,378	4,898,376	771,450
Connecticut	405	1,379,000	-
Delaware	32	70,274	-
Florida	26,339	8,663,997	-
Georgia	17,642	1,716,625	-
Idaho	6,973	3,756,183	8,850
Illinois	585,158	7,223,753	2,309,675
Indiana	447,611	3,824,095	606,550
Iowa	111,430	2,645,025	7,450
Kansas	179,238	7,080,824	277,270
Kentucky	618,879	4,561,535	3,213,500
Louisiana	350	3,096,447	97,750
Maine	1,656	676,400	-
Maryland & D. C.	22,627	2,060,200	137,900
Massachusetts	1,431	1,200,625	-
Michigan	6,928	19,013,650	2,300
Minnesota	35,842	12,011,452	-
Mississippi	2,989	1,450,475	-
Missouri	85,638	8,931,932	141,912
Montana	62,536	5,748,174	23,000
Nebraska	1,731	207,901	-
Nevada	30,542	3,201,525	200
New Hampshire	492	177,825	-
New Jersey	69	3,136,075	-
New Mexico	13,306	592,025	305,300
New York	12,231	13,583,471	55,100
N. Carolina	30,506	3,618,800	12,300
N. Dakota	25,822	149,107	28,975
Ohio	238,143	10,283,986	211,000
Oklahoma	111,379	10,214,335	262,121
Oregon	19,257	3,634,440	250
Pennsylvania	920,422	42,716,231	29,247,590
Rhode Island	184	104,650	-
S. Carolina	3,846	763,640	-
S. Dakota	657	1,159,605	1,800
Tennessee	107,921	3,404,820	295,950
Texas	74,741	8,404,490	65,100
Utah	16,875	7,492,265	817,995
Vermont	3,880	394,150	-
Virginia	62,351	3,426,150	1,200,190
Washington	43,860	8,058,276	623,025
West Virginia	478,930	5,183,300	12,751,825
Wisconsin	4,127	4,584,000	50
Wyoming	34,477	1,289,900	911,850
TOTAL 1st 11 MOS. 1927	4,764,317	266,025,410	59,133,161

NOVEMBER, 1927

	Black blasting powder	High explosives other than permissible	Permissible explosives
	Kegs (25 pounds)	Pounds	Pounds
Quantity used for:			
Coal mining	406,445	3,047,125	5,088,111
Metal mining	4,369	6,772,445	16,000
Quarrying and nonmetallic mineral mining	16,849	5,171,141	78,700
Railway and other construction work	19,014	3,578,399	13,100
All other purposes	14,979	3,196,450	256,150
TOTAL NOVEMBER 1927	461,656	21,765,560	5,452,061

JANUARY TO NOVEMBER, 1927, INCLUSIVE

	Black blasting powder	High explosives other than permissible	Permissible explosives
Quantity used for:			
Coal mining	4,045,667	31,658,634	56,457,282
Metal mining	80,954	80,429,705	136,175
Quarrying and nonmetallic mineral mining	221,272	73,454,702	513,770
Railway and other construction work	230,467	44,210,722	214,161
All other purposes	185,957	36,271,647	1,811,773
TOTAL 1st 11 MOS. 1927	4,764,317	266,025,410	59,133,161

TABLE C - Quantity of explosives sold for use in COAL MINES in November 1927 by manufacturers rendering monthly reports.

(Including cumulative figures for the first eleven months of 1927).

State	Black blasting powder Kegs (25 pounds)		High explosives other than permissible Pounds		Permissible explosives Pounds	
	This month	This year to date	This month	This year to date	This month	This year to date
Alabama	5,020	79,006	49,300	555,644	407,550	4,467,900
Arkansas	7,477	64,132	1,500	73,700	1,000	20,683
Colorado	3,285	38,005	35,800	225,675	54,350	715,250
Illinois	79,546	578,176	70,975	448,700	298,375	2,108,275
Indiana	48,245	439,010	122,325	974,625	70,875	543,925
Iowa	16,033	107,070	6,150	139,550	1,000	6,000
Kansas	22,518	170,148	78,450	666,026	50,095	274,920
Kentucky	35,285	585,866	66,500	884,200	208,550	2,971,930
Maryland	1,600	18,426	19,400	60,400	11,150	82,850
Michigan	- - -	4,927	2,975	47,925	- - -	100
Missouri	10,609	61,572	19,700	168,150	6,250	49,962
Montana	6,959	47,487	2,800	16,200	- - -	9,950
New Mexico	- - -	3,705	- - -	20,600	48,000	293,050
North Dakota ..	6,657	25,333	22,700	90,700	2,500	14,975
Ohio	17,805	200,434	37,900	387,400	950	54,400
Oklahoma	12,600	99,936	24,500	154,000	40,236	227,532
Penna. (Bitum.)	26,723	323,879	71,675	1,169,533	900,200	11,456,570
Tennessee	8,074	91,238	13,600	153,950	10,600	276,800
Texas	1,230	21,285	600	6,300	- - -	- - -
Utah	20	20	1,550	37,100	64,500	794,995
Virginia	4,390	48,947	8,250	220,100	43,350	1,171,340
Washington	1,198	12,498	1,800	68,600	49,950	384,300
West Virginia .	32,883	453,553	48,950	906,825	939,900	12,348,475
Wyoming	5,780	23,111	4,600	47,650	114,400	770,900
Other States ..	805	10,091	200	83,375	2,000	103,900
Total (Bitum.).	354,742	3,507,855	712,200	7,606,928	3,325,781	39,148,982
Penna. (Anth.).	51,703	537,812	2,334,925	24,051,706	1,762,350	17,308,300
Grand Total as reported ...	406,445	4,045,667	3,047,125	31,658,634	5,088,131	56,457,282
Est. total inc. non-reporting companies	) Anth.	548,900		25,595,000		17,334,000
	) Bitum.	3,579,000		8,097,000		39,204,000
Total reported plus estimate .		4,127,900		33,692,000		56,538,000

NOTE: As several companies do not furnish the Bureau of Mines with monthly reports of their sales, the above figures for any given State may be subject to material revision. The figures as given are based on reports received.

TABLE D - Number of pounds of pyrotol distributed by the Department of Agriculture, Bureau of Public Roads, during the period of November 1, 1927 to November 30, 1927.

State	State Highway Department Roads	Farmers Land Clearing	Bureau of Public Roads	Other Government Departments	Total
	Pounds	Pounds	Pounds	Pounds	Pounds
Alabama	10,000	20,000	- -	- -	30,000
California	- -	50,000	- -	20,000	70,000
Georgia	60,000	77,000	- -	- -	137,000
Idaho	- -	97,750	- -	- -	97,750
Indiana	20,000	- -	- -	- -	20,000
Michigan	- -	82,000	- -	- -	82,000
Minnesota	- -	318,000	- -	- -	318,000
Montana	- -	- -	24,000	- -	24,000
Nebraska	20,000	32,400	- -	- -	52,400
New Mexico	- -	- -	- -	200	200
North Carolina	21,000	160,150	- -	- -	181,150
Ohio	- -	16,000	- -	- -	16,000
Oregon	16,000	222,200	100	- -	238,300
South Carolina	- -	21,850	- -	- -	21,850
South Dakota	- -	21,000	- -	- -	21,000
Texas	70,000	27,000	- -	- -	97,000
Virginia	25,000	16,000	- -	- -	41,000
Washington	47,500	261,900	5,000	121,500	435,900
Wisconsin	- -	52,000	- -	- -	52,000
Total November	289,500	1,475,250	29,100	141,700	1,935,550
Total October	205,700	2,238,850	144,300	60,000	2,648,850
Total September	125,000	1,450,550	24,000	70,300	1,669,850
Total August	199,500	220,250	336,400	24,000	780,150
Total July	140,850	444,000	122,000	20,000	726,850
Total June	225,300	685,250	108,300	72,900	1,091,750
Total May	162,000	825,500	26,000	352,100	1,365,600
Total April	291,550	1,669,550	7,500	222,000	2,190,600
Total March	249,500	1,916,860	- -	103,700	2,275,060
Total February	170,750	1,020,150	- -	- -	1,190,900
Total January	93,000	704,050	- -	20,000	817,050
Grand Total	2,142,650	12,650,260	797,600	1,091,700	16,682,210

622.09
Un 32 mo
cop. 2

Serial No. 2846,
December, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

PROPERTIES OF CALIFORNIA CRUDE OILS

III - ADDITIONAL ANALYSES

By A. J. Kraemer[1]

Introduction

This report on the physical and chemical properties of crude oils of California is one of a series on the producing districts of the United States. It includes a short discussion of results, tabulated data, and individual analyses of California crudes. Analyses of crude oils from the fields of Fresno, Kern, Los Angeles, Orange, and Ventura Counties have been published in Serials 2595[2] and 2608[3]. The analyses reported in this paper cover samples that were obtained subsequent to the publication of Serials 2595 and 2608.

The samples were obtained by members of the San Francisco office of the Bureau of Mines. The collecting of samples was facilitated by the courtesy of representatives of oil companies in California.

The methods used in testing and analyzing the samples are described in detail in Bureau of Mines Bulletin 207[4]. For a discussion of the interpretation of crude oil analyses as made by the Bureau of Mines, see Serial No. 2806[5].

---

[1] A. J. Kraemer, associate petroleum chemist, Bureau of Mines, Department of Commerce.

[2] Kraemer, A. J. and Smith, H. M. Properties of typical crude oils from the producing fields of California, Bureau of Mines, Reports of Investigations No. 2595, April 1924.

[3] Kraemer, A. J. and Smith, H. M. Properties of California crude oils II Additional Analyses. Bureau of Mines, Reports of Investigations, No. 2608, May 1, 1924.

[4] Dean, E. W., and others, The analytical distillation of petroleum and its products. Bureau of Mines Bulletin 207, 1922, 82 pp., 15 cents. Obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C.

[5] Smith, N. A. C. The interpretation of crude oil analyses. Bureau of Mines, Reports of Investigations No. 2806, May 1927.

A complete copy of this serial may be obtained by writing to the Bureau of Mines, Department of Commerce, Washington, D. C.

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

622.09
Un 32mo
cop. 2

Serial No. 2847
December, 1927.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

PREVENTION OF HYDROGEN SULPHIDE POISONING IN HANDLING AND REFINING HIGH-SULPHUR PETROLEUMS

By H. C. Fowler[1]

THE LIBRARY OF THE
JUL 23 1958
UNIVERSITY OF ILLINOIS

Introduction

Hydrogen sulphide associated with the gases and vapors from certain crude oils now produced in the United States has forced a serious health and safety problem upon the petroleum industry. Although the presence of hydrogen sulphide in or occurring with Mexican crudes has been known for some time, it was not until recently that crude oils which give off poisonous amounts of hydrogen sulphide have been produced to any extent in the United States.

The injurious effects of this poisonous gas were first recognized by the refiners along the Atlantic and Gulf Coasts upon receiving shipments of crude petroleum from Mexico. The problem of combating the hazards of the gases and vapors given off by this petroleum become more important as the use of Mexican crude increased. In 1925, the Bureau of Mines and Public Health Service under a cooperative agreement with the American Petroleum Institute, studied the causes and effects of hydrogen sulphide poisoning. Bureau of Mines Bulletin 231[2] is a report of this investigation, and although written with special reference to refineries, it nevertheless contains much information that is of value to the producer of petroleum.

With the development of the Texas Panhandle, and fields in the southwestern portion of the State, symptoms were observed similar to those which brought about the initial investigation. In July, 1926, the Bureau of Mines made a study of the hazards of hydrogen sulphide in the oil fields. A report[3] was published based upon the findings of this field investigation.

Since that time, several fatal accidents have occurred in the oil fields and at refineries where hydrogen sulphide gas is present, and recently the Bureau of Mines has received numerous requests for information pertaining to hydrogen sulphide poisoning. This indicated need for a wider dissemination of available data on the subject has led to the preparation of this report. Frequent reference has been made to the two previous reports, because the data already gathered have a direct application to the hazards and methods of protection in handling and refining the high-sulphur petroleums of Texas and other States.

---

[1] - Petroleum Engineer, Bureau of Mines, U. S. Department of Commerce.

[2] - Sayers, R. R., and others, Investigation of toxic gases from Mexican and other high-sulphur petroleums and products: Bulletin 231, Bureau of Mines, 1925, 108 pp.

[3] - Yant, W. P., and Fowler, H. C., Hydrogen sulphide poisoning in the Texas Panhandle, Big Lake, Texas, and McCamey, Texas, oil fields: Serial No. 2776, Bureau of Mines, October, 1926.

A simple method of determining the percentage by volume of hydrogen sulphide in a gas is appended for the reference of those who wish to ascertain the concentrations of any atmosphere that may be encountered during the handling and refining of high-sulphur oils.[4]

The fact should be kept in mind that there are three general divisions to the hydrogen sulphide problem that have a definite and interlocking relationship to one another. These may be stated as:

1. Health and safety -- the human phase.
2. Corrosion -- the equipment phase.
3. Treating -- the process phase.

The subjects of corrosion and treating demand much scientific research based upon fundamental physical and chemical laws. Already considerable work has been done by various federal bureaus, technical societies, and individual companies. To give here a resume of all the important findings of these investigations would not be feasible.

However, every successful effort made toward controlling corrosion of equipment and every treating process that removes sulphur compounds from the oil should be of some aid in controlling the hazards of producing, transporting, and refining high-sulphur crudes. All human hazards can not be eliminated; but a thorough knowledge of the properties and effects of hydrogen sulphide, together with proper methods and equipment for working in contaminated atmospheres, will help to bring the total number of accidents to the minimum.

GENERAL CHARACTERISTICS OF HYDROGEN SULPHIDE

Hydrogen sulphide (H_2S) is a colorless gas heavier than air[5] (Sp.Gr. (Air = 1) = 1.1895). In relatively low concentrations it has a "sickly sweetish" taste and a disagreeable characteristic odor which in some localities has lead to the use of the term "rotten gas." Hydrogen sulphide burns with a blue flame in air. It also forms explosive mixtures with air, the lower limit of complete flammability being 5.9 per cent H_2S and the upper limit 27.2 per cent.[6] The products of complete combustion are sulphur dioxide (SO_2) and water vapor. Hydrogen sulphide is an "acid" gas, soluble in water. At 32°F one volume of water absorbs 4.37 volumes of H_2S. It becomes less soluble as the temperature is raised, until at 104°F, only 1.86 volumes of the gas are absorbed by one volume of water. If the solution is boiled or aeriated, all the gas may be driven off.

---

[4] - From time to time, samples of gas containing H_2S have been collected and shipped for analysis. Frequently, when such samples are kept for some time in steel cylinders, the analysis of the gas is quite different from that obtained on samples of the same gas analyzed in the field immediately after sampling. This is due to the affinity of H_2S for metals and its unstability. Also, if samples are collected by water displacement, the analysis may not be representative on account of the solubility of the gas in water.

The method, as outlined, requires very little equipment but gives results sufficiently accurate for field safety studies of H_2S. Where closer determinations are required, exact laboratory methods should be used.

[5] - In the petroleum industry, hydrogen sulphide usually occurs with methane (CH_4), ethane (C_2H_6), and other hydrocarbon gases. The composite mixture may be lighter than air.

When exposed to H_2S, white lead paint, the principal constituent of which is basic lead carbonate, turns to a dark brown or almost black color, due to the formation of lead sulphide. Many houses and signs in oil field communities of the Texas Panhandle and southwestern Texas are witness to this fact. Copper, lead, and silver tarnish rapidly when exposed to hydrogen sulphide.

In the petroleum industry, H_2S is recognized as a highly corrosive agent. Leaks due to pitting, and the sticking of valves and other fittings, causing frequent replacements of equipment at places where H_2S is known to exist, give proof of its deleterious affinity for metals.

Tests have been made to determine the solubility of hydrogen sulphide in petroleum oils.[7] The sample of crude which was used had a gravity of 20.8° A.P.I. and contained 3.77 per cent sulphur. The gas in the container above the oil showed from 0.63 to 0.80 per cent H_2S. In making the test, a 2000 c.c. sample of the oil was saturated with H_2S gas, and a gentle current of air at room temperature was passed over the surface of the oil. During the first 7.5 hours, 1911 c.c. (24.5 per cent of the total H_2S) were given off. At the end of 81 hours (effective time) 7,424 c.c. of H_2S had been given off. This amount represented 95 per cent of the total H_2S. Further tests on the H_2S remaining in the oil, made by bubbling air through the oil, indicated that the total H_2S in solution was 7,814 c.c. and would require 120 hours for its complete removal. Agitation or aeriation would have increased the rate of giving up the gas. Compared with the figures for absorption by water, as given above (See line 3), one volume of the above sample of oil, at an average temperature of approximately 75°F, absorbed 3.91 volumes of H_2S.

This test shows that oils will lose much of their free H_2S if allowed to stand exposed to the air, and in a system that is not vapor tight, there will be an appreciable decrease in the amount of dissolved H_2S from the time the oil leaves the well until it reaches the refinery. But open storage and mechanical aeriation cause evaporation losses of valuable light hydrocarbons. Therefore, this procedure does not suggest an economical way of ridding the oil of its hydrogen sulphide.

Furthermore, it is difficult to determine just what part of the H_2S is in solution in a natural crude and what part is evolved as a result of chemical action. Most organic sulphur compounds will give off H_2S when they are subjected

---

6 - Jones, G. W., Yant, W. P., and Berger, L. B., The explosibility of hydrogen sulphide in air; Industrial and Engineering Chemistry. Vol. 16, No. 4; April, 1924, pp. 353-355.

7 - Bureau of Mines Bulletin 231, pp. 25-26.

to heat, and "distillations show that much of the sulphur in the crude oil will be obtained as H_2S in the gas."[8] This means that even though a high-sulphur oil has been allowed to stand for a considerable time or has been completely aeriated, or washed, there will yet be large amounts of hydrogen sulphide present in the vapors when the oil is run in crude stills or cracked in pressure stills. Large quantities of H_2S are evolved at the point where the oil begins to crack actively. Samples taken from vapor lines at stills charged with, or running, high-sulphur petroleums, when the temperature was 500°F and above, show concentrations of H_2S in excess of 20 per cent by volume. One sample taken at a coke still while running naphtha tested 71 per cent H_2S.

PHYSIOLOGICAL ACTION - TOXICITY OF HYDROGEN SULPHIDE

Hydrogen sulphide is an extremely toxic gas. This fact hardly needs proof in view of the many fatal accidents[9] that have been caused by breathing it; yet some uninformed people are inclined to belittle the hazards of exposure.

Yant[10] says: "Hydrogen sulphide and hydrogen cyanide (hydrocyanic acid) may be classed in the same category of poisonous gases. From comparative data the dosage of hydrogen sulphide required to kill most animals in a very short time is even less than for hydrogen cyanide namely, 0.10 to 0.20 and 0.30 per cent in air, respectively."

The Bureau of Mines[11] made a series of elaborate tests on various animals (because it was unsafe to use human beings). It was found from tests made on dogs, which have a susceptibility similar to men,[12] that concentrations as low as 0.06 to 0.08 per cent of H_2S by volume may cause unconsciousness and death.

As nearly as has been determined, hydrogen sulphide reacts on the nervous system causing a paralysis of the lungs. This suffocation is quickly followed by heart failure if the action of the respiratory center is not returned to its normal action within a relatively short time.

Hydrogen sulphide gas in high concentrations quickly deadens the sense of smell. For this reason its characteristic odor, as initially sensed in the lower concentrations, is not a definite warning of danger. In many cases a person would probably not have time to be warned by the odor before be became unconscious. The margin between consciousness and unconsciousness, and between unconsciousness and death is very narrow. Probably one breath of the gas may be sufficient to cause asphyxiation.

---

[8] - Bureau of Mines Bulletin 231, p. 31.

[9] - Bureau of Mines Serial No. 2776, pp. 7-9.

[10]- Yant, W. P. supervising chemist, Health Laboratory Section, and Sayers, R.R., chief surgeon, Bureau of Mines. Hydrogen sulphide as a laboratory and industrial poison, Journal of Chemical Education, Vol. 4, No. 5, May, 1927, pp. 613-619.

[11]- Bureau of Mines Bulletin 231, pp. 59-80.

[12]- Lehmann in Archiv für Hygiene, Vol. 14, 1892 pp. 135-189.

Exposure to low concentrations (as low as 0.005 per cent over a long period of time[13]) may cause irritations of the eyes ("gas eyes") and irritations of the breathing passages and lungs. The eyes may become red and inflamed, or feel as if they have red pepper or sand in them. A person may become "light shy." When the breathing passages are affected a dry cough may develop, or a person may feel a fullness in the chest. These are all symptoms of poisoning caused by low concentrations of hydrogen sulphide.

TREATMENT

Home treatments for cases of "gas eyes" or irritations of the nose, throat, and lungs are not advisable because complications may develop. A competent doctor should be consulted.[14]

Gassed Victims

Hydrogen sulphide, in high concentrations, however, acts so quickly when breathed that there is no time to call a doctor before beginning treatment. Artificial respiration should be given immediately after rescue. Those rescuing the victim of gas must exercise every precaution or they too may be overcome. A doctor should be summoned without delay; but not at the expense of stopping artificial respiration. If an inhaling apparatus[15] is available, oxygen should be given in connection with artificial respiration. Under no circumstances should artificial respiration be suspended until the man resumes breathing or it is definitely established that life is extinct.

PLACES WHERE HYDROGEN SULPHIDE MAY BE ENCOUNTERED

Hydrogen sulphide has been found in injurious amounts throughout almost every step of handling and refining high-sulphur crudes from the casing head at the well until they reach the semi-final stage of finished products. Steam still receiving houses and tanks containing finished gasoline and kerosene are about the only places where the possibilities of hydrogen sulphide poisoning are negligible.

---

13 - Bureau of Mines Bulletin 231, p. 80.

14 - A treatment that has been found very satisfactory by doctors who have had a wide experience with subacute poisoning in the oil fields and at refineries is repeated here from Bureau of Mines Serial No. 2776.

Conjunctivitis: 1. Relieve pain by drops of butyn, or butyn and epinephryn, or in severe cases holocain.
2. Follow with campho borate. One doctor varies this practice by using boric acid ointment.
3. Drops of neo-silvol or argyrol (5 to 10 per cent).
4. Throughout the treatment use hot compresses, alternating with a cold compress if the pain is too great.

Rhinitis, Laryngitis, and Bronchitis: Irritations of the nose, throat and lungs are treated symptomatically.

15 - Bureau of Mines Bulletin 231, p. 79.

The hazards due to the occurrence of hydrogen sulphide at drilling wells and methods employed to combat them have been discussed.[16] Texas fields that are known to produce hydrogen sulphide are listed here together with the average H_2S content of the gas, produced from wells in each field, given in per cent by volume.[17]

Field	H_2S content in gas from wells per cent by volume
Panhandle ("Big Lime")	0.50 to 0.65
Big Lake	10.00
McCamey	6.00
Crane-Upton	8.00 to 12.00

It is very likely that new fields in these and other regions will show similar concentrations and great care will have to be exercised to cope with the hazards of poisoning. In addition to the drilling hazards, the occurrence of accidents has proved the following places and operations to be outstanding as possible sources of danger:

(1) Producing wells:- gas leaks around casing heads and other connections, gaging tanks, cleaning tanks; (2) Pipe Lines:- gaging tanks, cleaning tanks, leaks and breaks on line, leaks in manifold and pump houses, loading tank cars, cleaning and repairing tank cars; (3) Refineries and Gasoline Plants:- gaging tanks, cleaning tanks, stills (batch, continuous run, rerun, coking, pressure), vapor lines (leaks and breaks), gas scrubbers, condenser boxes, receiving houses, rundown tanks, pump houses, compressors, drains and sewers, loading racks, cleaning and repairing tank cars.

A TYPICAL CASE OF POISONING

Many accidents caused by hydrogen sulphide poisoning could be prevented if the men had a better understanding of the toxic action of the gas and realized the need of wearing suitable breathing equipment while in the gaseous area. The fallacy of trying to enter an area where hydrogen sulphide gas is present without protection afforded by an approved breathing apparatus has been given tragic proof upon more than one occasion. A typical example of this was brought to the attention of the Bureau of Mines recently.

Two men were in the receiving house of a cracking unit. This house was a one story brick structure, approximately 22 x 70 feet in lateral dimension with 10 feet headroom to the bottom chord of the roof trusses. There were wide doors at either end of the building and large open windows along the sides. A series of 2-inch pipes brought the cracked distillates from the condenser boxes to a row of

---

16 - Yant, W. P., and Fowler, H. C., Hydrogen sulphide poisoning in the Texas Panhandle, Big Lake, Texas, and McCamey, Texas, oil fields: Serial No. 2776, Bureau of Mines, October, 1926.

17 - A simple method of making rapid determinations of hydrogen sulphide by titrating with iodine solution, is appended to this report.

vertical drums which acted as gas separators inside the house. These were connected by means of 1½-inch lines, to a 4-inch header, supported on the bottom chords of the roof trusses. The vapors were separated from the fluid in the drums and in due course reached the gasoline compressor plant.

A pressure still was just being charged with high-sulphur crude from the Crane-Upton district of Texas. The pressure had been read and recorded a short time previous to the accident. The records showed about 50 pounds - for the still was just being brought up to pressure.

The men noticed a leak in one of the 1½-inch valves on the vapor line connecting the third drum from the end to the header. This drum was not more than 12 feet from the door and opposite a window. Failing to realize the danger, the men obtained a short ladder and placed it against the drum; probably with the idea of closing off an auxiliary valve on the outlet line. There was also a valve on the inlet line between the drum and the wall of the building, which could be reached inconveniently from the floor.

Evidently the man on the ladder never reached the top valve, for when the valve finally was closed with an extension handle from the outside of the building, enough turns had to be taken on the wheel of the valve to indicate that it was not even partly closed. He was found a short time later, hanging with his arm caught between a rung of the ladder and some of the piping. The other man, standing on the floor, who reached for the valve on the intake line became unconscious almost immediately also.

Four men, seeing the condition of their fellow workers attempted to rescue them. Three of the rescue party were overcome by the gas before they were able to bring the first two victims out of the house. One of the rescue party stated afterward that just as he entered the house, he held his breath but was finally forced to take an inhalation. He states that his sensation, as nearly as he can remember, was one of pungent exhaust vapors like those from an automobile. Further than that he knew nothing more until he "came to" in the fresh air some time later with someone giving him artificial respiration.

Without question the quick work of men trained in first-aid saved the lives of at least two of the rescue party. One man was only slightly affected, another was revived in two or three minutes; the third man was brought back to consciousness in 15 minutes; but it required one hour and 15 minutes of uninterrupted artificial respiration with oxygen to produce signs of life in the fourth man. Even after that, inhalations of oxygen were given for short intervals for several hours longer.

The two men who attempted to close the valves and shut off the leak did not regain consciousness, although every effort was made to revive them with artificial respiration and inhalations of oxygen. Two doctors, who arrived shortly after the accident, commended the first-aid work which was continued unceasingly until after it was apparent that both men were dead. It is possible that these men were dead before they were removed from the receiving house, because the gas coming off this vapor line showed high concentrations of hydrogen sulphide and the vapors contained many of the lighter hydrocarbons. Also, the outrush of gas from the broken line may have caused a deficiency of oxygen in the atmosphere breathed by the men. The physiological action of atmospheres markedly low in oxygen is very rapid.

As in many other observed cases of acute poisoning, followed by immediate rescue and treatment, the recovery of the rescue party was rapid. After a few days all four of the men returned to their work with no apparent ill effects. The men stated that they experienced varying degrees of headache, sleeplessness, and weariness for several hours after their experience; but these conditions soon cleared with complete rest under the care of a doctor.

This accident is typical of many others that have occurred in the petroleum industry. It shows the need for all men who work in the vicinity of hydrogen sulphide to learn of its highly toxic effects and to wear suitable breathing equipment while working in it.

WARNINGS TO WORKMEN

All men working in oil fields or at pump stations, gasoline plants, and refineries that handle high-sulphur crudes and the gases therefrom, should be adequately warned regarding the poisonous nature of hydrogen sulphide. Suitable warnings signs should be posted in conspicuous places about the plant and at tanks, pipe line and compressor stations, and wherever tests prove or indications show a dangerous condition exists or is likely to develop.

One large company has made use of the following sign:

POISON GAS

Oil and gas in this vicinity may contain enough hydrogen sulphide to cause unconsciousness and death without warning.

Observe the Following Precautions
Under All Conditions.

1. Never stand on the side of any opening where escaping gas will blow toward you.

2. Never enter a tank, cellar, or other inclosed places, where from leaks, breaks, or otherwise this gas has accumulated, without wearing proper breathing equipment, safety belt, and life line.

> Note: Blower type hose masks afford the best protection against this gas, and this equipment will be available for use under direction of the foreman.

3. Do not try to determine the presence of harmful quantities of this gas by its odor.

4. If a break in a line occurs, hold your breath and get out of the danger zone. Report all dangerous conditions and get instructions.

5. In case a man is overcome, get him to fresh air (using precautions for self protection); give artificial respiration at once; call a doctor.

The sign is 11 x 19 inches, printed with red ink on a weather proofed cardboard. It makes an outstanding poster which few men will fail to read and heed. If such a poster were signed by the superintendent, additional weight would be attached to it. In addition, this same company has prepared and distributed to all of its employees a small booklet telling some of the outstanding dangers of hydrogen sulphide and giving instructions for procedure when the gas is encountered. The text is written in simple language with no attempt to discuss the technical phases of the subject. In brief outline it tells what H_2S is; what it does; treatment; after effects; breathing equipment; dangerous working places; and in conclusion states:

> "It is the duty of everyone to become as fully informed about this subject as possible and help with suggestions, careful action, and by telling the other fellow who does not realize the dangers of hydrogen sulphide gas."

Augmenting these methods of reaching its employees with printed information, this company is holding round table meetings where the foreman, safety engineers, and small groups of workmen discuss the salient points regarding their specific problems growing out of the hazards of hydrogen sulphide poisoning. As soon as possible all men will be given first aid instruction.

SAFETY DEPENDS UPON OPERATING FORCE

Too much importance cannot be placed upon the value of suggestions and details of what takes place in plant operations coming from the men who perform the work of handling and refining petroleum. Processes have been developed and installed through the laborious and painstaking care of corps of highly trained technical men who have studied the many problems and built up the complex system from the very foundation of fundamental laws. And yet upon the men actually operating this equipment depends the safe running of the plant. The designing and construction engineers provide factors of safety to cover contingencies, but the "safety factor" rests largely with the men who use the equipment.

It is no overstatement to say that very often the engineering department does not get direct contact with the operating force. For this reason it fails to hear directly what the men think and say regarding their troubles with equipment, material, and methods of operation. Sometimes the troubles are imaginary but more often they are very real and should be investigated from a technical viewpoint. Periodic conferences with plant operators, suggestion boxes, and a closer relationship between the safety department and the technical and scientific corps will help forestall many impending failures.

Safety engineers meet the men daily and talk over their problems with them. When questions involving design or research are presented for solution, the safety department should be in a position to ask for and receive the whole hearted support of the engineering and technical staff in arriving at a satisfactory solution - for the very basis of engineering is safety of men and equipment and efficient operation. This does not mean that every suggestion submitted by the men will be put into practice. If this method were adopted, it is likely that plant operations would often be disrupted. But every suggestion should be given due weight to determine its merit or fallacy.

THE NEED OF INCREASED INSPECTION OF EQUIPMENT

Present processes at many refineries have made imperative the need for closer and more systematic inspection together with the testing of material, equipment, and methods of operation. It is of utmost importance to "catch the breaks" before they occur. Very often, only a man working daily with the equipment is able to do this. A new man should be trained to look for the weak spots.

With the introduction of pressure equipment new demands were placed upon material and men. Now that large amounts of high sulphur crude are being sent to various refineries--especially in the Mid-Continent and Gulf districts--the demand have increased. At first, much of the high-sulphur oil was run through equipment that had been in service for some time with processes using oils containing very little sulphur. The increased corrosive action brought about by the presence of large amounts of H_2S and other sulphur compounds caused many leaks to develop; other leaks may be expected in the future.

Leaks and Corrosion

Leaks are always a potential hazard around a refinery or gasoline plant, but when the escaping vapors are not only explosive[18] but highly toxic as well, the hazards are multiplied several times. The outside appearance of metal tubing seldom gives indication of the extent of pitting or reduction of cross sectional areas of the metal. Not only is frequent inspection and maintenance necessary by men definitely trained in this work, but every man at the plant should report immediately any condition that may indicate a leak or lead to a break. Any symptom of subacute poisoning of the men working in an area should call for an investigation at once to determine the source of escaping gas.

Gages and Quick Closing Cocks

Pressure gages and quick acting cocks that automatically close when gage glasses break require frequent attention. It has been reported that these valves sometimes fail to work. They should be closed and opened several times at the beginning of each shift so as to loosen any scale or foreign material that may have accumulated during the previous shift. If they fail to work properly they should be replaced with new ones. Equipment made of corrosion resisting material will help this condition.

One refinery has placed the duty of inspecting and calibrating all gages under the supervision of the safety department. At frequent periodic intervals, all gages are checked against accurate test gages and any that are faulty or defective are replaced by new instruments or some that have been overhauled and repaired. Such an organized plan assures the proper working of these important indicators at all times. Gages have been found where inspections have been infrequent, that gave readings from 10 to 50 pounds in error.

Valves

The sticking of hand wheel valves, where it becomes necessary to use a wrench to open or close them should suggest a potential hazard.

Corrosion may be the indirect as well as direct cause of failure and subsequent leakage, as in the case of the valve which allowed gas to escape in the receiving house and caused the death of two men, as described above.

---

[18] - For the inflammability and explosibility of gasoline and other hydrocarbon vapors see Bureau of Mines Technical Papers 115, 117, 119, 121 and 150; for the explosibility of hydrogen sulphide see Footnote 6, p. 3, this report.

This $1\frac{1}{2}$-inch valve was a rising stem, yoke type; that is, the bonnet was held in place by a strap completely encircling the body of the valve. Inspection of this valve revealed no great amount of corrosion. However, the disc and seat were not absolutely free from pitting, and there may have been leakage past the valve. There is every indication that the body of this valve had been cracked previous to the beginning of the run, for numerous tests were made on similar valves, and 1400 pounds pressure did not rupture these valves. The original valve was not subjected to more than 55 pounds per square inch vapor pressure. A 17-inch lever arm was then placed on the wheel of one of these valves and loaded. The body broke when the suspended weight reached $62\frac{1}{2}$ pounds. This would give a moment or torque acting on the valve stem of approximately 90 foot-pounds. Computations based upon the thread specifications and pitch of the wedge shaped disc show that a force of 11,000 pounds per square inch was necessary to cause rupture. This force could not be applied without mechanical means to increase the leverage given by the wheel of the valve. Other valves were tested and only broke when subjected to similar loading

These tests seem to indicate that previous to the run, the valve refused to close tightly. It is thought that someone placed a wrench on it to cause the valve to seat. In so doing the body was probably fractured unknowingly and when the pressure reached the neighborhood of 50 to 55 pounds, the fracture opened and allowed the gas to escape. Small valves especially are not designed for opening and closing with a wrench. The need of reporting a faulty valve that refuses to seat, such as that typified by the foregoing example, must be impressed upon every workman.

Acquaintance with Processes and Equipment

A definite idea of the general piping system, with the location of the major control and emergency valves is knowledge that every man should have. This statement should not be taken to imply that every man in the plant should acquaint himself with the whole piping layout. Such a method would be impractical and inadvisable. But more general knowledge of the location of valves that can be closed in case of a break or leak may save lives. Conspicuous labels or "tags" on emergency valves would be of great benefit if a line broke.

PROPER USE OF BREATHING EQUIPMENT

The use of breathing equipment for various operations that must be carried out in irrespirable atmospheres has become quite general in the petroleum industry during the last few years. The occurrence of hydrogen sulphide in various fields has increased the need for these mechanical means of protection. Considerable literature has been published on the subject of breathing equipment suitable for vapors containing H_2S.[19] However, observation has shown that the advantages and limitations of the various types of apparatus are not fully understood throughout the industry.

---

19 - Bureau of Mines Bulletin 271
Bureau of Mines Technical Paper 348
Bureau of Mines Serial No. 2776

There are three main types of breathing equipment that have been used successfully in the petroleum industry. These are:

1. The self contained oxygen breathing apparatus ($\frac{1}{2}$ hr. type)
2. Canister gas masks
3. Hose masks

Oxygen Apparatus

The oxygen apparatus is too complicated for general use, but when worn by specially trained men, it has been found particularly useful in some branches of the industry.[20]

Canister Gas Masks

The commercial canister mask was developed from experimental work which was done primarily to perfect a suitable army gas mask. In outward appearance, the two masks are not dissimilar, but the materials contained in each and the class of work for which each is suitable should not be confused.[21] The commercial canister mask is suitable to wear only in relatively low concentrations of gas. The safest practice is to wear it only where a man can remain for a short period of time without any protection.

The average commercial canister mask has a cubical content of about 600 c.c. Different chemicals and substances have the property of combining with or adsorbing (holding upon their surfaces) different gases. There are at least 12 different combinations of contents in commercial canister masks. It is important therefore, that an exact statement of conditions under which the masks will be used accompany every order for gas masks, so that the correct canister will be supplied by the manufacturers. For example, a 600 c.c. canister filled with activated charcoal will give protection against a one per cent concentration of gasoline and other hydrocarbon vapors for one hour, but its protection against a one per cent concentration of H_2S will be for only $3\frac{1}{2}$ minutes.

The same size of canister, filled with soda lime, will protect against a one per cent concentration of H_2S for 17 minutes but gives no protection against hydrocarbon vapors. Mixtures of soda lime and charcoal have protective limits intermediate between the figures given above.

These figures were determined from tests made at the Pittsburgh Experiment Station of the Bureau of Mines on the basis of an average man breathing at the rate of 32 liters (1.13 cu.ft.) per minute under ordinary working conditions. (Some men under conditions of forced breathing will use twice this amount for a short time). The relative humidity during the tests was 50 per cent and the room temperature was about 77°F. Canisters holding 1500 and 3600 c.c. were tested also.

---

[20] - For a complete description of this equipment see Katz, S. H., and Bloomfield, J. J., Gas Masks for Gasoline and Petroleum Vapors; Technical Paper 348, Bureau of Mines, 1924, 37 pp.

[21] - Technical Paper 348, pp. 2-3.

"The life of canisters increases directly with the volume of adsorbent ***** and in general increases inversely as the concentration of the gas."[22]

The greatest objection to the canister masks is the fact that canisters must be selected on the basis of the kind and concentration of the gases to be encountered. Training and experience are required to do this correctly, and rigid inspection must be maintained at all times to guard against a possible oxygen deficiency in the atmosphere and the "breaking down" of the canister because it has been used too long. A canister type of gas mask does not create or generate a respirable atmosphere, but only removes low concentrations of objectionable gas. For these reasons, men who are instructed to wear canister masks should be just as cautious to avoid standing in the direct flow of gas from any opening as they would be if they had no protection whatever.

Hose Masks

In general, hose masks are the most satisfactory type of breathing equipment for use in the petroleum industry because of their simplicity of operation and the positive protection which they give. There are few places where this apparatus will be greatly inconvenient, and its use removes many of the limitations of the other two types. Statements that men cannot or will not work with hose masks are usually based on prejudice.

A hose mask brings fresh air to the wearer through a hose, 50 or more feet long; lengths up to 150 feet have been used successfully. The most satisfactory type is equipped with a manually operated blower on the air intake end. This fan assures positive pressure on the line and face piece, thus keeping out any gas that might otherwise gain access to the equipment. The fresh air coming to the face piece has a cooling effect on the wearer and helps keep the lenses in the face piece from becoming fogged. Those masks which bring the air supply to the face piece through two flexible inhalation tubes allow the most freedom of movement. These are joined to the end of the hose at the back with a substantial Y connection and are brought over both shoulders to another Y connection with the face piece.

For all petroleum industry use, a special oil proof hose (1-inch diameter) should be specified.

If care is taken to have the intake end in good air and the face piece and connections tight, a man can work for an indefinite time without danger. (A case has been told of a man who remained inside of a gas holder, on an emergency job, for 6 continuous hours, wearing a hose mask).

---

22 - Bureau of Mines Bulletin 231, p. 92.

Workmen who are to use masks should be given complete instructions before entering an irrespirable atmosphere. They should inspect the equipment carefully for possible leaks and see that all connections are tight. If they have never worn masks, they should put on the face piece and try it our for some time in fresh air before going into the gas. This will have a tendency to overcome any misgivings as to its workability.

To place the mask over the face; first, the sides of the mask should be grasped with both hands and the chin thrust well forward into the mask. Then the thumbs, starting at the chin, should be brought up along the cheeks causing the edges to fit tightly to the configuration of the face. The hands should then pass back over the head, securing the head straps in place, above and below the ears. The head straps should be adjusted to fit snugly. The mask should next be tested for leaks by grasping the flexible tubes which connect the hose with the face piece and pinching them closed. If there is no leakage, one or two inhalations and exhalations through the exhaust valve will cause the face piece to partially collapse and the edges will cling to the face. (A similar test should be made when a canister mask is to be worn by placing the palm of the hand over the bottom valve of the canister.)

Regardless of the type of breathing equipment worn, no workman should enter an inclosed "gassy" area, such as tank, cellar, or sewer manhole, without wearing a safety belt with life line securely fastened to it, and the other end in the hands of a responsible person, attended by a sufficient number of helpers to remove the man quickly, if need arises.

All hose masks are provided with a harness to which the end of the hose is fastened before it makes connection with the face piece. The most satisfactory types combine the harness and safety belt as one unit. It should be compulsory that a man fasten safety belt and supporting harness about him securely before putting on the face piece. A man was seriously gassed at a Mid-Continent refinery because he failed to buckle the harness around him as he should have done before entering a gas filled container. In moving about, with the face piece held in place only with the head straps, the weight of the hose pulled the mask from his face, and it was with difficulty that he was rescued.

After breathing equipment has been used, it should be thoroughly cleaned. Any accumulated oil on the outside of the hose should be removed and then thoroughly washed with water. The face piece should be cleaned and washed with a 2 per cent Lysol solution. The equipment should then be dried and put away in its container, ready for emergency use at any time. If the apparatus is allowed to remain in an unkept condition, it cannot be expected to give good service when needed. All breathing equipment should be inspected and tested at least every 30 days. The face piece and exhalation valves should be worked with the hands to keep the rubber pliable and thereby prolong its life.

METHODS OF PROTECTION AT VARIOUS WORKING PLACES

Gaging Tanks

The gaging of tanks presents a very definite hazard from hydrogen sulphide.

In Serial No. 2776[23] reference was made to the large numbers of dead birds and small animals which were frequently found near flow tanks in the Big Lake and McCamey fields of Texas. This in itself should cause gagers and others to approach these tanks with a great deal of caution; and only after being provided with protective breathing equipment. A case was cited, also, where a gager died from the effects of hydrogen sulphide gas which he breathed at the time of lifting a gage hole cover. Two other men and one dog are known to have died from the effects of gas on top of storage tanks in the fields of southwestern Texas. Probably the three men were overcome through lack of information or thoughtlessness; the dog through inquisitiveness.

Recently, in the Crane-Upton area, a pipe line gager started toward a battery of tanks for the purpose of running some oil. The tanks had been built in a "draw" or small valley. Upon going into this valley, the gager was overcome by the gas that had collected there. A number of men rushed to his aid, passing several gas masks on their way in. Eight men were overcome before someone had the presence of mind to put on a mask before attempting a rescue. All of the gassed men were revived, but it required one and one-half hours of artificial respiration for the first man who was overcome to regain normal breathing.[24]

The hazard, incidental to gaging, is not confined to producing fields. The following details of an accident that occurred recently at a refinery, nearly 1000 miles from the field where the oil was produced, show how necessary it is to exercise extreme precautions wherever oils containing hydrogen sulphide are gaged:

---

23 - Yant, W. P., and Fowler, H. C., Hydrogen sulphide poisoning in the Texas Panhandle, Big Lake, Texas, and McCamey, Texas, oil fields: Serial No. 2776, Bureau of Mines, October 1926, pp. 7-9.

24 - To the writer's knowledge, this is the first time in the United States that men have been overcome by hydrogen sulphide gas when not directly adjacent to the source of the escaping gas. The incident is not unlike one told by H. R. J. Conacher, Scottish Oils, Limited, Glasgow & London, of a certain valley in the Anglo-Persian fields of Persia. Men and animals passing through this valley at night were overcome frequently, and many were found dead. The natives considered the place under an evil spell. Investigation showed that hydrogen sulphide gas was being expelled from fissures in the rocks. During the daylight hours, the convection currents of that hot country caused enough air movement to prevent toxic concentrations, but at night the gas would settle in the lower parts of the valley. Finally the Anglo-Persian company was forced to erect barriers at either end of the valley. At sundown the gates are closed and are not opened until sunrise of the following day as a protection for the unwary traveler.

The gager climbed on top of a tank which contained pressure distillate to make the hourly gage of the contents. The crude petroleum from which this unfinished product had been made in one of the cracking processes of the refinery was from the McCamey, Texas, field. Contrary to the rules of the company, the gager had propped open the lid of the gage hole for convenience. He was overcome by the hydrogen sulphide and after falling remained in the toxic gas near the open gage hole until he was discovered nearly five minutes later by another gager. The second gager was overcome temporarily while assisting to remove the first man from the tank. All efforts to revive the gager who was first overcome failed.

At many refineries and pump stations where high-sulphur crudes and distillates are handled, gagers report symptoms of dizziness, nausea, and near asphyxia.

Venting Tanks Before Gaging

A person should never stand on the side of any opening where escaping gas will blow toward him. If it is necessary to gage a tank of high-sulphur oil and no protective equipment is available, the gager should stand well back on the windward side of the hatch. A rod or other means of lifting the cover will be safer than using the hands or stepping on the foot lever if the self closing type of hatch is used.

If there is internal pressure on the tank, causing the gas to come out in stream line flow, and the method of gaging requires standing over the opening, (and no protective equipment is available) the gage should not be taken until pressure inside and outside of the tank is equalized. Under some conditions, this method would require a prohibitive amount of time. However, where it is necessary to resort to this practice, it would be better to equip the tank with a vent controlled by a hand valve (in addition to the pressure and vacuum relief valves) that could be opened before gaging and closed again after the gage was completed. The vent should carry the vapors away from the tank completely, or at least extend several feet above the head of a tall man. Some companies run a vapor line from their flow tanks into their stock tanks, thus saving some of the lighter gases that come with the oil. Where this method is used, it will be necessary to close off this connecting vapor line during the operation of gaging. Otherwise vapors will continue to flow out of the vent or the gage hatch when it is opened.

Methods of Gaging

With the ordinary "innage" or "wet line" method of gaging (determining directly the depth of oil in the tank by reading the oil mark on the tape) a man is not forced to hold his face over the opening. By exercising the proper precaution he can run the tape out until the plumb bob touches bottom, reel in, and read the tape while standing back away from the flow of gas.

Some companies require "outage" gaging of their tanks. (The wet mark is read on a graduated plumb bob and this reading is deducted from the reading of the tape taken at an established mark on top of the tank.) Where this method is used, it is almost necessary to look down into the tank to see when the bob reaches the surface of the oil.

If no mask is available and it is necessary to make an outage gage, it has been suggested that a preliminary gage be made to determine the approximate level of the oil. This can be done in the ordinary method while standing well back from the gage hole, as previously described. With this figure in mind, the gager, after wiping the line and bob clean, can then run in carefully - standing back from the stream line flow - and take his reading for outage. The calibrated bob will give him 6 or 8 inches "leeway." This expedient will increase the time of gaging a tank, but a few additional minutes spent in keeping out of the gas may be the means of preventing a severe case of "gas eyes," headache, or possible asphyxia.

But all of the foregoing methods are precautionary rather than preventative measures. Under conditions like those which may be encountered in the Crane-Upton area, where even the surrounding atmosphere of a tank may be contaminated with toxic amounts of hydrogen sulphide gas, or at refineries where tanks are housed in buildings, these suggestions have no place. Under any condition it is realized that they consume time and allow considerable wastage due to evaporation losses of light hydrocarbons. It has been estimated[25] that a 55,000 bbl. tank, half filled with oil and under one ounce pressure, will require 10 minutes to equalize to atmospheric pressure through the gage hole. During this time the equivalent of 20 gallons of gasoline will be lost. There is also the possibility that the wind will change or the gager will become incautious, with harmful results.

Use of Masks in Gaging

The safety and speed of gaging can be greatly increased by the use of breathing equipment. Ordinarily, a suitable canister mask will be adequate for gaging tanks, because the harmful gases are quickly dissipated in the air. However, this condition should be checked frequently by collecting samples of air near the gage hole when it is open and testing for H_2S concentration as outlined in the appendix. This sampling should be done under conditions of low barometer and little or no wind movement if possible; for these are the worst conditions the gager will have to meet.

If the concentration is high (over 2 per cent) or if continuous gaging calls for frequent replacement of canisters, a light portable hose mask without blower can be used advantageously. This equipment is similar to the hose mask with blower, described on page 14 and following, except that the intake end of the hose is fitted with a funnel covered with a fine wire gauze to prevent particles of dirt and other material from entering the hose. A spike and hook may be used to keep the wearer from dragging the intake end into the gaseous area. However, in gaging most tanks, all that would be necessary would be to drop the end of the hose over the side of the tank, well below the eave line. The whole equipment with mask, belt, and 25 feet of hose weighs 21 pounds. Nearly all gaging - except where escaping gas has contaminated the surrounding atmosphere - can be accomplished with 15 feet of hose. This would reduce the weight and the complete apparatus could easily be carried from one tank to another.

---

[25] - Pamphlet, "Oceco" published by the Oil Conservation Engineering Company, Cleveland, Ohio, July 1, 1925, p. 15.

Yant[26] has suggested that a permanent pipe, leading from fresh air to a point near the gage hole, be placed on the tank. A shorter hose, with suitable type of quick connection, could then be used. This would lighten the apparatus carried by the gager. The connection should be made before the gage hole is opened.

Tanks Equipped With Gage Wells

A number of companies in the southwestern fields of Texas have equipped their gas tight tanks with gaging wells to protect their gagers.

A joint of 6 or 8 inch old casing (some companies use galvanized stove pipe casing) is cut to proper length and placed in a vertical position directly beneath the gage hole. The lower end is slotted for a distance of several feet and is made fast to the tank bottom with brackets or other means, Some companies raise the lower end several feet off bottom and support the well on a frame. When this is done the slotting is not necessary. The top end of the well is flanged, gas tight, to the bottom of the gage hatch. This forms a liquid seal and prevents the escape of vapors.

But any internal pressure or vacuum on a gas tight tank will cause a small rise or fall of the fluid level in the well relative to the fluid level in the tank. For example, one ounce of internal pressure on a tank containing oil of 35° A.P.I. gravity at 60°F will raise the level in the well 2 inches. One ounce of vacuum would depress it an equal amount. If the tank is equipped with pressure and vacuum relief valves, thereby keeping the pressure in the tank moderately uniform, the difference between the gage in the well and the actual fluid level in the tank will be relatively constant. For determining estimates of daily well or lease production, this will be accurate enough for the purpose required of the gage in some cases. Some companies have placed a few perforations in the top of the well, below the tank roof, in an effort to overcome the discrepancy; although this will keep the two fluid levels equal as long as the gage hatch is closed tightly, upon lifting the hatch, the equilibrium will be unbalanced as soon as the small amount of gas in the well has escaped; there will be atmospheric pressure on the fluid in the well and atmospheric pressure plus the vapor pressure inside of the tank. For this reason, there is little or no advantage gained in placing holes in the top of the gage well. Moreover they allow some poisonous vapors to escape upon opening the gage hatch.

For pipe line runs, or wherever accurate gages are required in a vapor tight tank equipped with a gage well, the surest method is to place a water manometer or U-tube on the tank conveniently adjacent to the gage hole. At the time of gaging, the difference between the internal and external pressure is read. These pressure differences are readily converted into correction factors of fluid level in the tank. In fact, the scale on the manometer can be calibrated for any desired gravity of oil and the plus or minus factor applied to the gage reading directly. A draft gage would give closer readings than a manometer--if this is desired.

---

[26] - Yant, W. P., supervising chemist, Health Laboratory Section, Bureau of Mines. Personnel communication.

More than ordinary care is required on the part of the gager to note whether the correction factor is plus or minus; but the protection against poisonous vapors is greatly increased.

Some tanks have been equipped recently with various designs of automatic tank gages. Where these are used the hazard to the gager from H_2S and other vapors ceases to exist.

For companies that require "outage" gaging on their tanks a suggestion has been offered, namely, provide the tank roof with a gas tight window or dead light, capable of withstanding the maximum pressure on the tank; the bob and tape to be lowered through a small gage hole nearby, provided with some suitable arrangement to prevent the escape of gas. Some studies in design would have to be made to obtain a dead light that could be cleaned easily of any accumulations of oil and dirt on the underside of the glass.

The foregoing are only a few suggested methods of reducing the hazards of gaging. Considerable thought and study should be given to improve the methods of gaging and the design of gage holes.

Platforms

Regardless of the method of gaging and type of gage hole, it is advisable to build a platform with substantial handrails and toe boards around hatches that are close to the tank rim. Several men have fallen from the tops of tanks with resulting serious injury or death, when temporarily affected by gas.

Cleaning Tanks

The cleaning of tanks should always be undertaken with considerable forethought. After a tank has been drained of all the oil that will flow or can be pumped out of it, the bottom will be covered with a layer of residue, varying in depth from several inches to several feet - depending upon how long the tank has been in service and the kind of oil that has been stored in it.

Even after the tank has been "floated" (that is, all of the tank bottoms that will float removed by washing with water) and thoroughly steamed with all hatches and manholes open, it is surprising how tenaciously the vapors cling to the interior. Then too the residue may contain many volatile hydrocarbons and other gases that will become apparent only when the mass is stirred or when men begin to move about in it.

Wherever possible, it is advisable to have a regular tank cleaning crew who have been trained in this work and who work together effectively. The men become accustomed to working with breathing equipment, and under a competent foreman, soon learn what precautions should be taken. When a new man joins the gang, he should be given the benefit of the experience of the older members.

Tank cleaning, or entering tanks for any purpose after they have contained high sulphur oils, invariably calls for the use of hose masks. Canister masks are not advisable because high concentrations of gas are likely to be encountered regardless of the amount of preliminary washing, steaming, and venting.

Lengths of hose up to 150 feet have been used satisfactorily in tank cleaning operations. This amount of footage will allow a man to move about over as great a radius as is necessary in the largest tanks.

In all petroleum industry work, a special reinforced hose, 1-inch in diameter, that is impervious to hydrocarbon vapors, should be used. No other type should be permitted because lighter hose is not impervious to oil vapors.

Although the 1-inch hose is treated to withstand the action of oil, it is advisable to keep it off the bottom as much as possible. This may be accomplished by stringing light sand line on the posts which support the roof at a height just above the head of a tall man. The hose can then be hooked on this line, with sliding hooks made of copper. If this method is not feasible, light collapsible tripods of wood can be made. Copper wire between the legs will hold them rigid when in use. These can be placed at convenient intervals as a man enters a tank and the hose laid on the apex of the frames. Some simple method of supporting the hose will facilitate the movements of a man working in the tank, but it should be realized also that the hooks or tripods will add to the difficulty of rescue if a man should be overcome by the gas inadvertently.

Very often, one or more sheets of the bottom ring are removed prior to cleaning a tank. This allows additional ventilation and the residue can be removed through the opening with the use of scrapers and drag line operated from the outside. Several serious accidents have taken place when removing one of these sheets. In one instance, after most of the rivets had been cut, the hydrostatic head of residue inside the tank forced the plate out and men working on the outside were deluged with the semifluid mass. The plate should be bolstered until ready for removal with a gin pole or A-frame and a block and tackle.

Care must be taken when cutting rivets that a spark will not be caused which may ignite inflammable gas if such is present. To prevent an occurrence of this kind, one company has used the method of playing a stream of water on the rivets as they were being cut.

Men working inside of tanks should not only take precautions against poisonous gases but should be very careful about fires and explosions. The atmosphere inside of a tank that is being cleaned is likely to be an explosive mixture.[27]

---

[27] - Gasoline vapors in air - 1.5 to 5.5 per cent. Burrell, G. A. and Boyd, H. L., Inflammability of mixtures of gasoline vapors in air, Tech. Paper 115, Bureau of Mines, 1917, pp. 9-10.
Other hydrocarbon vapors (methane, etc.) in air-5 to 15 per cent. Burrell, G. A. and Gauger, A. W., Limits of complete inflammability of mixtures of mine gases and of industrial gases with air, Tech. Paper 150, Bureau of Mines, 1917, pp. 5-7.
Hydrogen sulphide in air - 5.9 to 27.2 per cent. Footnote 6, this report.

All tools and scrapers should be of wood or non-ferrous metal. (Sparks from brass have been observed. Copper is apparently safe.) Manila cordage should be used for drag lines. Flash lights, if used, should be of a permissable type, approved for use in gaseous atmospheres. Permissable cap lamps are satisfactory. Extension cords from light circuits should never be used.

As a guide to tank cleaners, one company has adopted the following general instructions:

GENERAL INSTRUCTIONS FOR CLEANING TANKS

Crude - Gas Oil - Naphtha Distillate - Fuel Oil

1. All tanks to be cleaned must first be floated and pumped out.

2. Before any tanks are opened, notify safety department so that safety man can be on the job to assist in keeping the hose masks in safe condition and see that they are properly used.

3. All pipe lines into or out of tank must be blanked off.

4. Manholes and top hatches should be opened and the tank washed and steamed.

5. All men working inside of tank must wear hose masks with safety belt and life line provided for that purpose.

6. No iron or steel tools will be permitted inside the tank.

7. No lights except approved electric safety lights will be permitted.

8. Only three men permitted in tank at one time.

Stills

The greatest danger to workmen of poisoning from hydrogen sulphide at stills of various types - with the exception of possible leaks in equipment as previously discussed - is during the cleaning and repair operations. A shell still should be thoroughly washed, steamed, and ventilated. Some companies steam for two hours and ventilate for two hours longer. The atmosphere should be tested - collecting samples and titrating them as described in the appendix - before a man is allowed to enter the still, and even then he should be attended by helpers on the outside - in case of an emergency. Where compressed air or a blower type of fan is available, circulation through the still while the men are working in it can readily be maintained. If motors are used, care must be taken to provide proper equipment that will not lead to ignition and possible explosion of gas - air mixtures.

Some still cleaners and repair men have complained of the presence of sulphur dioxide (SO_2) in the fire boxes of stills that burn gas given off in the refining processes of high-sulphur crudes. Such a condition is quite possible. Sulphur dioxide is one of the products of combustion of H_2S, as described under the heading, "General Characteristics of Hydrogen Sulphide." Sulphur dioxide is 2¼ times heavier than air (sp.gr. (Air = 1) = 2.2638) and pockets of this gas may collect in the fire box if not carried up the stack by the draft after the still has been shut down. Concentrated sulphur dioxide is a very toxic gas, but the danger from poisoning by SO_2 is not great because very small amounts cause coughing and smarting of the eyes to such an extent that a man going into a fire box would be driven out, if SO_2 were present, before he was harmed by the gas. If ventilation - either natural or forced - does not clear the condition in a short time, a gas mask provided with an "acid gas" canister or a hose mask should be worn.

Condensers

Fatal poisoning has occurred in condenser boxes at the time of making repairs or putting in new sections of the coils. One of the possible sources of H_2S in the coils is the backing up of gas from the sewers. As a safeguard against this, all drawoffs to sewers should have water seals and the sewers should be vented.

As in the operations of tank cleaning, a set of instructions or rules of procedure will help forestall accidents in condenser boxes. Before starting any work on a coil, the inside should be washed and steamed. All connecting lines should be blanked off. No man should be allowed to work inside a condenser box without wearing a safety belt and life line attached. Men should be stationed at a safe position on top to give aid if necessary. If a coil is to be broken, the men in the box should wear hose masks.

Drains and Sewers

Refinery drains and sewers have the possibility of collecting fluids containing high concentrations of H_2S throughout the whole plant. They should be considered an outstanding hazard. The solubility of H_2S in water was discussed under "General Characteristic Hydrogen Sulphide"- page 3. There is also the possible danger of underground gas lines leaking and the escaping gases permeating the ground and finding their way into the sewers. Drains and sewers should be well trapped and vented. The vents should be placed where they will carry off the gases without contaminating the atmosphere breathed by men, or create a fire hazard. No man should enter a sewer manhole without wearing a hose mask and life line. The explosion hazards in sewers should be carefully watched and no light used except an approved safety flash light.[28]

Receiving Houses

The construction, arrangement, and equipment of receiving houses should be given special attention, for in these places where men are constantly at work, the whole system is often under positive pressure. A number of fatal accidents have occurred at different refineries not unlike that described under the heading, "A Typical Case of Poisoning."

---

28 - Burrell, G. A., and Boyd, H. T., Quantity of gasoline necessary to produce explosive conditions in sewers: Technical paper 117, Bureau of Mines, 1916 p. 17.

Buildings should be open as much as possible and well ventilated. A blower type of fan properly installed will help keep the atmosphere free of stray gas from look boxes and other sources. The accumulation of explosive mixture must be watched carefully. No design of motor or other electrical equipment should be used that will arc and cause ignition.

Many refineries have discontinued the use of open look boxes and have installed closed types with faucet drawoffs. The open look box is extremely dangerous from the standpoint of fire and explosion hazards. Due to the refining of high-sulphur oils, the danger of a workman being overcome by H_2S, or of developing severe conjunctivitis ("gas eyes") or irritation of the breathing passages and lungs, has made this type of look box even more objectionable. A man was recently overcome at a Mid-Continent refinery, while taking a sample from one of these open look boxes with a long handled dipper. If it is necessary to work under these conditions, proper breathing equipment should be worn while taking samples.

All lines leading into receiving houses should have emergency valves, or long handle extensions, on the outside. A small leak under several pounds pressure will quickly fill the house with toxic gas, allowing no time to close off the valves inside the house.

Many refineries have steam piped into the receiving houses for fire protection. The control valves should always be outside the building at a safe distance. In case of a leak giving out H_2S, this emergency equipment will aid greatly in driving out the gas.

As another emergency measure - similar to that of placing fire extinguishers on the outside of receiving houses in addition to those inside - one company has placed emergency hose masks at both ends of the receiving houses, about 15 feet outside the doors. The masks and hose are kept in ventilated, water tight, dirt proof containers of sheet metal supported on substantial frames of pipe. The containers are arranged so that the whole equipment comes out ready for use upon pulling the handles of a drawer.

Canister gas masks are not adequate for high concentrations of gas such as would occur in case of a break inside a receiving house.

Loading Racks and Tank Cars

The same general precautions should be taken in loading tank cars as in gaging tanks. Ordinarily a proper canister mask will give protection, but a loader will have to use judgment about looking into domes or he may find to his sorrow that he has expected too much of the canister mask.

In cleaning and repairing tank cars, the same procedure of steaming and ventilating should be followed as in cleaning other tanks. Hose masks with blowers and life lines should be worn by all men entering tank cars.

Other Hazardous Places

Specific instructions for various other places and operations where hydrogen sulphide may be encountered can only be determined through a study of individual plants. Gas scrubbers, pump houses, meter houses, pipe manifold pits, and compressor stations all have many features that may develop leaks and breaks. Many of the safeguards and precautions, which various companies are using, as previously described in this report, will have application to these places as well.

Above all, constant inspection of equipment and care in operation, giving due weight to the need of instructing workmen in the hazards of hydrogen sulphide will prevent many accidents in the handling and refining of high-sulphur petroleums.

ACKNOWLEDGMENTS

This report was made under the general supervision of H. H. Hill, chief petroleum engineer, Bureau of Mines. The State of Oklahoma cooperated.

The writer is greatly indebted to H.P. Rue, associate refinery engineer, Petroleum Experiment Station, Bartlesville, Oklahoma, for a personal communication giving an outline of a satisfactory method for determining hydrogen sulphide by titrating with iodine solution, which has been appended to this report; and for reading the manuscript and giving many helpful suggestions.

To the companies and individuals who gave so liberally of their time and the benefit of their experience, the writer wishes to express his appreciation and to thank especially those companies who generously granted permission for the use of data relative to accidents on their properties which were caused by hydrogen sulphide. It is hoped that methods of preventing similar occurrences at other places have been adequately deduced from the experiences.

H. C. Miller, petroleum engineer, San Francisco office and W. P. Yant, supervising engineer, health laboratory section, Bureau of Mines, gave many valuable suggestions.

N. A. C. Smith, superintendent, and F. W. Lane, petroleum chemist, of the Petroleum Experiment Station, Bartlesville, Oklahoma, read the manuscript and gave many constructive criticisms.

The writer wishes to thank all who assisted in the preparation of this report.

A SATISFACTORY METHOD FOR THE DETERMINATION OF HYDROGEN SULPHIDE BY TITRATING WITH IODINE SOLUTION.[29]

Solutions Required

One-tenth normal solution of iodine (1/10 N.) made up as follows - 12.692 grams of pure iodine are dissolved in 300 cc. of distilled water in which 18 grams of pure potassium iodide have been dissolved. Add distilled water to make the volume up to one liter (1000 cc.)

Starch solution used as an indicator made up as follows - Rub 2 grams of starch into a paste with a little water (distilled) - add to 200 cc. of boiling water (distilled) with stirring. Pour solution into 200 cc. of cold water (distilled). Allow to stand and settle, decant and use clear liquid. Add to a few drops of chloroform or saturate the solution with pure sodium chloride for preserving. It may be necessary to make up this solution from time to time as it will not keep indefinitely.

Apparatus Required

One clear glass bottle of about one liter capacity (with the volume determined accurately by filling with water and measuring the contents) fitted with a rubber stopper. One small calibrated burette (approximately 10 cc.) sealed onto one arm of a two way parallel bore stop cock. The single arm of the stop cock is inserted through a one hole rubber stopper of a size that will fit the bottle. (In the open position, liquid from the burette passes through one of the bores into the bottle. If the stop cock is turned 180°, a small amount of gas is permitted to escape from the bottle into the air through the other bore.) Six feet of 3/8 inch rubber tubing; one rubber aspirator bulb with double acting valves of hard rubber.

Method of Determination

In a dry bottle collect sample of gas through rubber tubing by displacement of air; use rubber bulb to fill bottle if necessary.[30] Stopper quickly. Add about 25 cc. of water (distilled) which contains about 5 cc. of the starch solution, avoiding loss of gas as much as possible, and quickly close with stopper attached to burette. Shake vigorously to facilitate solution of H_2S in the water. Fill the burette with the iodine solution and note the level of the iodine in the burette, let a drop or two of the iodine solution drop in the bottle containing the gas, and shake. If the blue color that first appears in the starch solution fades out, add more iodine a drop at a time and shake. Continue this until the blue color no longer fades out (on shaking vigorously). Record the amount of iodine solution used.

---

[29] - Personal communication, H. P. Rue, associate refinery engineer, Bartlesville Experiment Station, Bureau of Mines, Department of Commerce.

[30] - Where there is noticeable pressure, as from a flowing well or gas line, one end of the rubber hose is inserted into the bottle, until it reaches the bottom, and the other end is held directly in the stream line flow. Five or more minutes are usually enough to purge the bottle of air.

In sampling from tanks and other places where there is no noticeable pressure, the aspirator bulb, with a sufficiently long suction hose must be attached to the hose discharging into the bottle. About 200 compressions of the bulb are required to replace the air in a 1-liter bottle.

Care must be taken in collecting samples that the person doing the work is not overcome or affected by the gas.

Calculations

1 cc. 1/10 N. iodine = .0017938 grams of H_2S or 1.118 cc. of H_2S at 32°F and 760 mm.

For temperatures above 32°F the volume of H_2S will be slightly greater. For 77°F, the volume is as follows:

1 cc. 1/10 N. iodine = 1.22 cc. H_2S at 77°F.
Therefore the "factor" for 77°F = 1.22

Example

Assume the capacity of the bottle to be 1000 cc (1 liter); then the volume of the gas used would be 1000 cc.[31] 5 cc. of 1/10 N. iodine were used in the titration. The temperature at the time of the determination was 77°F.

The formula is as follows:

cc. of iodine x Factor x 100 = per cent H_2S by volume

Determination from data above

$$\frac{5 \times 1.22 \times 100}{1000} = 0.61 \text{ per cent } H_2S$$

Note: If the gas contains a high percentage of H_2S, it may be necessary either to fill the burette more than oncewith the iodine solution for one determination or to use a smaller volume of gas. (It may prove convenient to have on hand a small titrating bottle - 100 cc. capacity.) For low concentrations of H_2S gas it is often preferable to use weaker normal solutions of iodine.-- Reports of Investigations, Bureau of Mines, Department of Commerce.

---

[31] - Actually the volume of gas is equal to the capacity of bottle minus the volume of liquid used.

622.09
Un32mo
cop. 2

Serial No. 2848
December, 1927.

THE LIBRARY OF THE
JUL 23 19
UNIVERSITY OF ILLINOIS

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

ACCIDENT-SEVERITY RATES FOR CERTAIN MINES & QUARRIES

By W. W. Adams[1]

During the calendar year 1926 the United States Bureau of Mines conducted a safety contest among more than 250 mines and quarries. Each company endeavored to establish the best safety record by having the smallest loss of time from injuries in proportion to the total number of hours worked. The contest was known as the National Safety Competition. To the winning plant in each of five groups was awarded a bronze trophy, "Sentinels of Safety," the gift of the Explosives Engineer magazine. The contestants were arranged in five groups, and a trophy was awarded to the leading plant in each of the groups, as follows: (1) Anthracite mines; (2) bituminous coal mines; (3) metal mines; (4) nonmetallic mineral mines; and (5) open quarries and open-pit mines. Each competing company supplied the Bureau of Mines with a complete record of all lost-time accidents, that is, all accidents disabling an employee beyond the day or shift on which the accident occurred. The companies also reported the number of man hours of employment or exposure to hazard for each mine or quarry enrolled in the contest.

The total exposure represented by all companies was 95,055,815 man hours; the total number of accidents was 7,313. The accidents represented a loss of time equal to 799,493 man days, an average of 109 days per accident.

	Hours	Accidents	Lost days
Anthracite mines	23,880,425	2,339	178,252
Bituminous coal mines	26,436,344	1,788	283,048
Metal mines	15,411,121	1,779	115,880
Nonmetallic mines	3,888,849	307	24,900
Quarry and open-pit mines	25,439,076	1,100	197,413
Total, 1926	95,055,815	7,313	799,493
Total, 1925	68,413,283	6,249	580,835

From the records supplied by the companies the Bureau was able to determine the relative standing of the plants according to their accident-severity rates, that is, according to the number of man days of disability per thousand man hours worked. All days of disability were counted, including Sundays, holidays, and days on which the mine or quarry may have been idle, the object being to learn the true length of disability from injuries, not merely the number of "working days" lost.

---

[1] Statistician, Bureau of Mines, Department of Commerce.

Thirty States, extending from California to Massachusetts and from Minnesota to Texas, were represented in the contest. Twenty-five States were represented in the quarry and open-pit mine group, ten States in the metal-mine group, ten in the group of nonmetallic mineral mines, and ten in the bituminous coal-mine group. All of the anthracite mines were in Pennsylvania.

The contest revealed some remarkable safety records. Two metal mines, for example, were operated for the entire year without a lost-time accident; and fourteen quarries were operated without a lost-time accident. The significance of these accident-free records is realized more fully when it is remembered that none but relatively large plants participated in the contest. A minimum of 50 men underground or 25 men in the open quarry or open-pit mine was required by the rules governing the contest. The contest, however, included such surface workers as were connected with the mine or pit. It also included coarse crushing at quarries.

The leading mine in the anthracite group had an accident-severity rate of 0.3, as compared with an average rate of 7.8 for the entire anthracite group. The leading bituminous coal mine had a rate of 0.2, as against an average rate of 10.7 for the group. A rate of 0.07 was the best record among the nonmetallic mineral mines, as compared with a group rate of 6.4. The leading metal mine's rate was zero, as compared with an average rate of 7.5 for the metal-mine group. A rate of zero was also established by the leading quarry as against a rate of 7.3 for the quarry and open-pit mine group.

These comparisons emphasize the fact that individual companies are meeting with marked success in the prevention of accidents and that the average rates for large groups of mines or for the industry as a whole are by no means an indication of the best that can be accomplished by individual companies. Indeed, an interesting revelation afforded by an examination of the records was the fact that most of the individual companies had accident-severity rates that were lower than the averages for their respective groups. It was the minority of the companies, rather than the majority, whose rates were chiefly responsible for the group rates being as high as they were. Eighty-two per cent of the quarries had accident-severity rates better than the average for the quarry group. The percentages for the other groups were 82 for nonmetallic mineral mines, 75 for metal mines, 69 for bituminous coal mines, and 56 for anthracite mines. For all companies combined, the figures showed 75 per cent of the companies with severity rates lower than the general average for all companies. Although these percentages were based on relatively small numbers of plants, they are believed to be representative of larger groups, and probably, to some extent at least, of the mining and quarrying industries as a whole. In the previous year, 86 per cent of the quarries and open-pit mines had individual plant rates that were lower and therefore better than the average group rate; 83 per cent of the nonmetallic mineral mines, 62 per cent of the metal mines, 61 per cent of the bituminous coal mines, and 50 per cent of the anthracite mines also had rates in 1925 that were better than their group averages. In all, 77 per cent of the plants had individual company rates lower than the average for all companies combined.

The foregoing comparisons are based on the accident-severity rates of the different plants. These rates are believed to be the best indication of the losses caused by accidents, yet it is interesting to note that the accident-frequency rates were usually also better for the larger proportion of each group of plants than for the groups as a whole; that is to say, usually more than 50 per cent of the individual plants in each group had individual plant accident-rates that were not as high as the accident rate for the group as a whole. This fact again indicates that it is the few plants, rather than the many, that are responsible for the average accident rates for large groups or for the whole industry not being more favorable than they are at present. The percentage of individual plants in each group having accident rates lower and therefore better than their respective group average rates was as follows:

	Severity		Frequency	
	1925	1926	1925	1926
Anthracite mines	50	52	50	44
Bituminous mines	61	69	73	45
Metal mines	62	73	56	64
Nonmetallic mines	86	82	50	65
Quarries and open-pit mines	86	92	59	65
All	77	73	73	67

In tabulating the data from the various companies, each fatal or permanent injury was charged with the number of lost days specified in the scale adopted by the Association of Industrial Accident Boards and Commissions. According to this scale, each fatality or permanent total disability is charged with 6,000 lost days. An injury causing permanent partial disability is weighted according to the degree of disability. Temporary disability was charged with the actual number of calendar days during which the injured employee was physically unable to work because of his injury. The following figures show the average number of days of disability per temporary injury and the average days per injury, including deaths, and permanent and temporary injuries when weighted in the manner stated, for the plants that participated in the 1926 safety contest:

	Temporary injuries (days)	All fatal and nonfatal injuries (days)
Anthracite mines	15.6	76
Bituminous coal mines	24.4	158
Metal mines	15.5	65
Nonmetallic mineral mines	18.9	81
Quarries and open-pit mines	17.1	179
All	18.1	109

The accident-frequency rate per million hours and the accident-severity rate per thousand hours for each group are indicated by the following figures:

	Frequency rate	Severity rate
Anthracite mines	97.9	7.464
Bituminous coal mines	67.6	10.707
Metal mines	115.4	7.519
Nonmetallic mineral mines	78.9	6.463
Quarries and open-pit mines	43.3	7.760
All	76.9	8.411

The above figures show that in 1936 the best record, so far as accident severity in relation to time lost was concerned, was made by the nonmetallic mineral-mine group. Thus this group, which represents underground mining operations, had a better record than the quarry and open-pit mine group, all of whose work is done in the open daylight. The second lowest accident-severity rate was that for anthracite mines, then metal mines, then the quarries and open-pit mines, and finally the bituminous coal-mine group.

Although accidents, in relation to number of man hours of exposure, occurred most frequently at metal mines, the average days lost per accident was lower than for any other group, hence the accident-severity rate, while not the lowest, was third from the lowest among the five groups. The group having the smallest accident-frequency rate was the quarry and open-pit mine group, yet the days lost per accident was the heaviest and the accident-severity rate was next to the highest of any group. Bituminous coal mines ranked second from the best in accident frequency, but here again the time lost per accident was high and the bituminous group therefore had a higher severity rate than any other group. The third best record in accident frequency was for nonmetallic mineral mines; this group also had the third best record as regards loss of time per accident, and it ranked the best of all groups in its accident-severity rate. The accident-frequency rate for the anthracite group was next to the worst among the five groups under consideration, but, as the average disability per accident was relatively low, the group's accident-severity rate was next to the best among the five groups, being surpassed in excellence only by the nonmetallic mines.

The accompanying tables present, in as much detail as the Bureau is at liberty to reveal, the statistical data covering accidents at certain mines and quarries during the calendar year 1936. Figures are also given to show the volume of exposure to risk; this factor is indicated by the number of man hours of work or presence at each of the various plants. The identity of the mines and quarries can not be published, but each company concerned has been confidentially advised of the key number of its own plant. The figures given in the tables relate to individual mines or quarries, not to operating companies.

Companies that operate mines or quarries not included in the accompanying tables are invited to compare the accident rates of their plants with the accident rates presented herewith to see the position in the tables which their plants would have occupied if they had been represented in the contest.

The Bureau of Mines would be glad to learn of any mine or quarry whose accident record was better than the leading plant in each of the five groups to which the attached figures relate.

GROUP 1.- ACCIDENT DATA FOR CERTAIN ANTHRACITE MINES IN 1926 1/

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm. dis.	Temp. dis.	Total	Deaths	Perm. dis.	Temp. dis.	Total		
1	68	145,000	--	--	4	4	--	--	41	41	27,586	0.283
2	262	526,536	--	--	23	23	--	--	332	332	43.682	.631
3	187	403,352	--	--	27	27	--	--	420	420	66.939	1.041
4	657	1,344,968	--	--	93	93	--	--	1,723	1,723	69.147	1.281
5	349	779,704	--	1	61	62	--	300	772	1,072	79.517	1.375
6	117	238,790	--	--	30	30	--	--	416	416	125.633	1.742
7	263	598,912	--	--	78	78	--	--	1,281	1,281	130.236	2.139
8	380	845,400	--	2	61	63	--	600	1,482	2,082	74.521	2.463
9	800	1,560,305	--	3	121	124	--	2,900	1,082	3,982	79.441	2.551
10	785	1,627,144	--	2	193	195	--	2,100	2,413	4,513	119.842	2.774
11	163	292,531	--	--	51	51	--	--	852	852	174.340	2.913
12	1,280	2,483,568	1	--	246	247	6,000	--	3,680	9,680	99.254	3.898
13	431	824,586	--	3	98	101	--	2,400	869	3,269	122.486	3.964
14	532	1,067,744	1	1	138	140	6,000	300	2,082	8,382	131.118	7.850
15	435	1,000,344	1	--	100	101	6,000	--	2,574	8,574	100.965	8.571
16	392	778,193	1	--	76	77	6,000	--	1,038	7,038	98.947	9.044
17	860	1,657,471	2	3	114	119	12,000	2,400	1,173	15,573	71.796	9.396
18	603	1,373,744	2	2	132	136	12,000	600	1,925	14,525	99.000	10.574
19	821	1,859,368	2	2	165	169	12,000	5,100	3,429	20,529	90.891	11.041
20	401	795,344	1	1	146	148	6,000	300	2,766	9,066	186.083	11.399
21	318	622,537	1	1	71	73	6,000	300	1,278	7,578	117.262	12.173
22	327	531,730	1	--	50	51	6,000	--	563	6,563	95.913	12.343
23	446	1,028,289	2	1	65	68	12,000	600	990	13,590	66.129	13.216
24	308	618,315	1	1	64	66	6,000	4,500	957	11,457	106.742	18.529
25	470	870,960	4	--	89	93	24,000	--	1,713	25,713	106.779	29.523
Totals & Averages	11,675	23,880,435	20	23	2,296	2,339	120,000	22,400	35,852	178,252	97.946	7,464
1925 Totals and Averages	2,792	4,890,295	5	1	457	463	30,000	600	6,782	37,382	94.677	7.644

1/ As the accident reports from mining companies are considered confidential by the Bureau of Mines, the identity of the mines to which this table relates is not revealed.

GROUP 2.- ACCIDENT DATA FOR CERTAIN BITUMINOUS COAL MINES IN 1926 1/ 2/

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm. dis.	Temp. dis.	Total	Deaths	Perm. dis.	Temp. dis.	Total		
1	444	815,715	---	---	7	7	---	---	165	165	8.581	0.202
2	244	429,902	---	---	5	5	---	---	119	119	11.631	.277
3	159	276,992	---	---	1	1	---	---	117	117	3.610	.422
4	267	465,529	---	---	4	4	---	---	227	227	8.592	.488
5	381	675,081	---	1	3	4	---	300	60	360	5.925	.533
6	480	876,250	---	---	9	9	---	---	485	485	10.271	.553
7	179	405,255	---	---	15	15	---	---	258	258	37.014	.637
8	184	462,836	---	---	36	36	---	---	303	303	77.781	.655
9	134	286,683	---	---	9	9	---	---	241	241	31.394	.841
10	77	169,169	---	---	4	4	---	---	160	160	23.645	.946
11	138	341,244	---	---	28	28	---	---	435	435	82.053	1.275
12	57	124,872	---	---	3	3	---	---	162	162	24.025	1.297
13	108	193,319	---	---	11	11	---	---	257	257	56.901	1.329
14	102	154,693	---	---	28	28	---	---	223	223	181.004	1.442
15	61	149,976	---	---	9	9	---	---	220	220	60.010	1.467
16	251	548,224	---	---	19	19	---	---	881	881	34.657	1.607
17	44	129,876	---	---	11	11	---	---	217	217	84.696	1.671
18	100	245,503	---	---	25	25	---	---	435	435	101.832	1.772
19	271	546,544	---	---	19	19	---	---	983	983	34.764	1.799
20	127	241,877	---	---	39	39	---	---	480	480	161.239	1.984
21	171	384,131	---	---	30	30	---	---	826	826	78.098	2.150
22	198	378,030	---	1	41	42	---	300	542	842	111.102	2.227
23	87	211,595	---	---	29	29	---	---	518	518	137.054	2.448
24	467	784,048	---	---	104	104	---	---	1,996	1,996	132.645	2.546
25	616	1,148,444	---	1	110	111	---	750	2,356	3,106	96.653	2.705
26	721	1,314,704	---	1	146	147	---	300	3,738	4,038	111.812	3.071
27	251	462,608	---	---	77	77	---	---	1,433	1,433	166.448	3.098
28	97	92,316	---	---	7	7	---	---	313	313	75.827	3.391
29	200	385,937	---	---	41	41	---	---	1,805	1,805	106.235	4.677
30	601	1,683,189	1	3	19	23	6,000	7,200	612	13,812	13.665	8.206
31	531	955,521	1	1	10	12	6,000	1,800	801	8,601	12.559	9.001
32	364	672,100	1	---	49	50	6,000	---	624	6,624	74.394	9.856
33	294	640,372	1	---	19	20	6,000	---	570	6,570	31.232	10.260
34	486	1,359,684	2	2	13	17	12,000	1,350	628	13,978	12.503	10.280

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm. dis.	Temp. dis.	Total	Deaths	Perm. dis.	Temp. dis	Total		
35	317	718,692	1	1	21	23	6,000	300	1,239	7,539	32.003	10.490
36	186	423,166	--	3	75	78	--	3,600	893	4,493	184.325	10.618
37	446	741,892	--	2	148	150	--	5,250	3,173	8,423	202.186	11.353
38	145	422,976	1	1	53	55	6,000	300	1,024	7,324	130.031	17.315
39	499	351,393	1	--	20	21	6,000	--	760	6,760	59.762	19.238
40	226	506,400	1	2	25	28	6,000	3,300	538	9,838	55.292	19.427
41	325	654,936	2	--	25	27	12,000	--	1,659	13,659	41.225	20.855
42	354	628,299	2	1	5	8	12,000	1,800	81	13,881	12.733	22.093
43	187	411,826	1	1	25	27	6,000	3,000	589	9,589	65.562	23.284
44	197	405,783	1	1	31	33	6,000	2,700	1,164	9,864	81,324	24.309
45	215	532,549	2	--	64	66	12,000	--	1,385	13,385	123.932	25.134
46	309	575,339	2	1	41	44	12,000	4,500	1,753	18,253	76.477	31.726
47	82	193,039	1	--	20	21	6,000	--	637	6,637	108.786	34.382
48	308	667,646	4	--	88	92	24,000	--	1,246	25,246	137.798	37.813
49	247	471,728	3	--	15	18	18,000	--	575	18,575	38.158	39.512
50	214	432,310	3	--	52	55	18,000	--	844	18,844	127.224	43.589
51	103	88,159	1	--	9	10	6,000	--	589	6,589	88.159	58.088
52	96	137,932	2	--	34	36	12,000	--	959	12,959	181.326	65.452
Totals & Averages	13,348	26,436,344	34	23	1,731	1,788	204,000	36,750	42,298	283,048	67.634	10.707
1925 Totals and Averages	14,164	24,227,266	28	28	3,053	3,109	168,000	37,500	48,535	254,035	128,326	10.486

1/ As the accident reports from mining companies are considered confidential by the Bureau of Mines, the identity of the mines to which this table relates is not revealed.

2/ Excluding the experience of one coal mine in which a major explosion occurred. If the experience of this mine be included, the severity rate for the bituminous coal mine group would have been 20.860 and the frequency rate would have been 69.509, obviously destroying the representative value of the figures.

GROUP 3.- ACCIDENT DATA FOR CERTAIN METAL MINES IN 1936 1/

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm.dis.	Temp.dis.	Total	Deaths	Perm.dis	Temp.dis	Total		
1	85	206,489	--	--	--	--	--	--	--	--	0.000	0.000
2	62	95,352	--	--	--	--	--	--	--	--	.000	.000
3	74	173,658	--	--	2	2	--	--	24	24	11.517	.138
4	153	380,793	--	--	19	19	--	--	126	126	49.896	.331
5	53	123,128	--	--	1	1	--	--	49	49	8.122	.398
6	80	200,480	--	--	8	8	--	--	91	91	39.904	.454
7	76	182,284	--	--	5	5	--	--	88	88	27.430	.483
8	100	244,088	--	--	17	17	--	--	182	182	69.647	.746
9	451	1,119,268	--	--	36	36	--	--	1,005	1,005	32.164	.898
10	65	157,222	--	--	14	14	--	--	148	148	89.046	.941
11	170	423,919	--	--	37	37	--	--	405	405	87.281	.955
12	96	231,215	--	--	48	48	--	--	319	319	207.599	1.380
13	192	467,974	--	1	22	23	--	300	359	659	49.148	1.408
14	109	267,816	--	--	29	29	--	--	404	404	108.283	1.508
15	44	109,168	--	--	12	12	--	--	165	165	109.922	1.511
16	61	146,208	--	--	11	11	--	--	236	236	75.235	1.614
17	49	122,632	--	--	12	12	--	--	219	219	97.854	1.786
18	52	125,152	--	--	19	19	--	--	230	230	151.815	1.837
19	64	183,688	--	--	19	19	--	--	388	388	103.436	2.112
20	78	228,928	--	--	36	36	--	--	490	490	157.255	2.140
21	56	127,744	--	--	16	16	--	--	283	283	125.251	2.215
22	95	228,000	--	--	42	42	--	--	511	511	184,211	2.241
23	117	332,420	--	--	49	49	--	--	748	748	147.404	2.250
24	115	330,560	--	--	65	65	--	--	829	829	196.636	2.508
25	90	216,000	--	--	46	46	--	--	563	563	212.963	2.606
26	45	113,536	--	--	13	13	--	--	367	367	114.501	3.232
27	80	193,016	--	--	19	19	--	--	690	690	98.437	3.575
28	164	398,169	--	1	7	8	--	1, 800	20	1,820	20.092	4.571
29	72	209,913	--	1	17	18	--	800	245	1,045	85.750	4.978
30	469	1,162,998	1	--	30	31	6,000	--	352	6,352	26.655	5.462
31	90	185,720	--	1	29	30	--	600	519	1,119	161.533	6.025
32	83	200,844	--	1	10	11	--	750	668	1,418	54.769	7.060
33	398	1,160,088	1	--	181	182	6,000	--	2,956	8,956	156.885	7.720
[illegible]	764	2,034,377	2	2	356	360	12,000	2,100	4,055	18,155	176.957	8.924
[illegible]	[illegible]	816,404	1	--	148	149	6,000	--	1,713	7,713	182.508	9.447

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm.dis.	Temp.dis.	Total	Deaths	Perm.dis.	Temp.dis	Total		
36	139	343,985	--	1	34	35	--	3,000	519	3,519	101.749	10.230
37	236	661,148	1	--	152	153	6,000	--	1,588	7,588	231.415	11.477
38	51	121,752	--	1	6	7	--	972	511	1,483	57.494	12.180
39	196	463,087	1	--	75	76	6,000	--	2,596	8,596	164.116	18.562
40	100	240,000	1	--	25	26	6,000	--	355	6,355	108.333	26.479
41	136	234,544	1	1	37	39	6,000	300	918	7,218	166.280	30.775
42	59	141,920	1	--	10	11	6,000	--	223	6,223	77.508	43.849
43	58	139,632	1	--	25	26	6,000	--	630	6,630	186.204	47.482
44	69	165,792	2	--	17	19	12,000	--	471	12,471	114.601	75.221
Totals & Averages	6,131	15,411,121	13	10	1,756	1,779	78,000	10,622	27,258	115,880	115.436	7.519
1925 Totals and Averages	5,925	14,612,607	15	9	1,950	1,974	90,000	9,000	27,575	126,575	135.089	8.662

1/ As the accident reports from mining companies are considered confidential by the Bureau of Mines, the identity of the mines to which this table relates is not revealed.

GROUP 4.—ACCIDENT DATA FOR CERTAIN QUARRIES AND OPEN-PIT MINES IN 1936.1/

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm. dis.	Temp. dis.	Total	Deaths	Perm. dis	Temp. dis.	Total		
1	82	254,318	--	--	--	--	--	--	--	--	0.000	0.000
2	75	238,037	--	--	--	--	--	--	--	--	.000	.000
3	103	232,703	--	--	--	--	--	--	--	--	.000	.000
4	78	227,750	--	--	--	--	--	--	--	--	.000	.000
5	71	213,605	--	--	--	--	--	--	--	--	.000	.000
6	56	170,041	--	--	--	--	--	--	--	--	.000	.000
7	62	149,308	--	--	--	--	--	--	--	--	.000	.000
8	60	141,702	--	--	--	--	--	--	--	--	.000	.000
9	40	122,687	--	--	--	--	--	--	--	--	.000	.000
10	34	102,340	--	--	--	--	--	--	--	--	.000	.000
11	30	90,143	--	--	--	--	--	--	--	--	.000	.000
12	32	85,797	--	--	--	--	--	--	--	--	.000	.000
13	25	70,170	--	--	--	--	--	--	--	--	.000	.000
14	32	57,692	--	--	--	--	--	--	--	--	.000	.000
15	186	557,056	--	--	1	1	--	--	2	2	1.795	.004
16	94	145,151	--	--	1	1	--	--	3	3	6.889	.021
17	41	91,042	--	--	1	1	--	--	2	2	10.984	.022
18	24	72,491	--	--	1	1	--	--	2	2	13.795	.028
19	61	200,904	--	--	2	2	--	--	6	6	9.955	.030
20	44	146,413	--	--	2	2	--	--	6	6	13.660	.041
21	120	438,000	--	--	1	1	--	--	19	19	2.283	.043
22	50	103,002	--	--	3	3	--	--	6	6	29.126	.058
23	64	214,995	--	--	3	3	--	--	14	14	13.954	.065
24	48	100,301	--	--	1	1	--	--	13	13	9.970	.130
25	45	100,000	--	--	5	5	--	--	15	15	50.000	.150
26	29	88,700	--	--	3	3	--	--	14	14	33.822	.158
27	41	115,563	--	--	4	4	--	--	21	21	34.613	.182
28	30	56,996	--	--	1	1	--	--	11	11	17.545	.193
29	40	121,169	--	--	7	7	--	--	25	25	57.771	.206
30	55	161,000	--	--	5	5	--	--	36	36	31.056	.224
31	45	153,854	--	--	2	2	--	--	38	38	12.999	.247
32	97	162,692	--	--	5	5	--	--	41	41	30.733	.252
33	30	101,426	--	--	2	2	--	--	28	28	19.719	.276
34	68	141,815	--	--	3	3	--	--	40	40	21.154	.282
35	98	213,000	--	--	4	4	--	--	61	61	18.779	.286

. 2848.

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm. dis.	Temp. dis.	Total	Deaths	Perm. dis.	Temp. dis	Total		
36	54	173,000	---	---	2	2	---	---	50	50	11.561	0.289
37	75	217,693	---	---	9	9	---	---	64	64	41.343	.294
38	53	178,030	---	---	3	3	---	---	57	57	16.851	.320
39	64	207,387	---	---	3	3	---	---	70	70	14.465	.338
40	135	444,887	---	---	9	9	---	---	155	155	20.230	.348
41	43	118,541	---	---	2	2	---	---	42	42	16.872	.354
42	62	172,636	---	---	3	3	---	---	64	64	17.378	.371
43	33	102,632	---	---	5	5	---	---	42	42	48.713	.409
44	97	287,532	---	---	4	4	---	---	120	120	13.911	.417
45	23	69,461	---	---	2	2	---	---	29	29	29.793	.418
46	46	159,141	---	---	6	6	---	---	67	67	37.702	.421
47	59	175,043	---	---	11	11	---	---	84	84	62.842	.480
48	60	177,225	---	---	2	2	---	---	87	87	11.281	.491
49	153	281,601	---	---	8	8	---	---	139	139	27.409	.494
50	169	424,255	---	---	13	13	---	---	222	222	30.642	.523
51	85	200,933	---	---	5	5	---	---	108	108	24.884	.537
52	66	135,944	---	---	---	---	---	---	77	77	---	.566
53	46	100,240	---	---	4	4	---	---	59	59	39.904	.589
54	74	216,000	---	---	5	5	---	---	128	128	23.148	.593
55	72	167,513	---	---	7	7	---	---	100	100	41.788	.597
56	43	110,008	---	---	4	4	---	---	70	70	36.361	.636
57	70	233,965	---	---	4	4	---	---	155	155	17.097	.662
58	14	44,319	---	---	1	1	---	---	30	30	22.564	.677
59	133	450,351	---	---	5	5	---	---	308	308	11.102	.684
60	26	59,682	---	---	1	1	---	---	46	46	16.755	.771
61	77	212,168	---	---	6	6	---	---	177	177	28,279	.834
62	45	70,951	---	---	4	4	---	---	61	61	56.377	[illegible]
63	35	107,354	---	---	2	2	---	---	99	99	18.630	[illegible]
64	44	108,835	---	---	7	7	---	---	101	101	64.318	[illegible]
65	102	165,686	---	---	3	3	---	---	158	158	18.107	[illegible]
66	33	97,922	---	---	5	5	---	---	96	96	51.061	[illegible]
67	50	136,584	---	---	7	7	---	---	136	136	51.251	.996
68	125	381,250	---	---	37	37	---	---	332	332	97.049	[illegible]
69	36	115,030	---	---	5	5	---	---	123	123	43.464	[illegible]
70	58	129,905	---	---	13	13	---	---	141	141	[illegible]	[illegible]
71	39	84,645	---	---	4	4	---	---	92	92	[illegible]	[illegible]

301

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm.dis.	Temp.dis.	Total	Deaths	Perm.dis.	Temp.dis	Total		
72	166	520,739	--	1	13	14	--	300	276	576	26.885	1.106
73	84	203,327	--	--	13	13	--	--	235	235	63.936	1.156
74	82	188,338	--	--	11	11	--	--	221	221	58.406	1.173
75	90	192,047	--	--	12	12	--	--	227	227	62.485	1.182
76	50	136,512	--	--	5	5	--	--	178	178	36.627	1.304
77	25	81,250	--	--	4	4	--	--	108	108	49.231	1.329
78	92	193,679	--	--	17	17	--	--	270	270	87.774	1.394
79	54	129,000	--	--	9	9	--	--	183	183	69.767	1.419
80	64	210,605	--	--	15	15	--	--	308	308	71.223	1.462
81	92	272,096	--	1	18	19	--	300	118	418	69.829	1.536
82	43	100,253	--	--	3	3	--	--	157	157	29.924	1.566
83	85	153,645	--	--	6	6	--	--	255	255	39.051	1.660
84	53	181,895	--	--	4	4	--	--	317	317	21.991	1.743
85	56	198,548	--	--	8	8	--	--	358	358	40.293	1.803
86	52	169,000	--	--	8	8	--	--	339	339	47.337	2.006
87	57	169,142	--	--	9	9	--	--	345	345	53.210	2.040
88	31	97,246	--	--	7	7	--	--	204	204	71.982	2.098
89	45	152,766	--	1	8	9	--	300	62	362	58.914	2.370
90	84	124,383	--	1	2	3	--	300	7	307	24.119	2.468
91	81	166,710	--	--	11	11	--	--	426	426	65.983	2.555
92	42	133,317	--	1	5	6	--	300	73	373	45.006	2.798
93	43	37,490	--	--	1	1	--	--	105	105	26.674	2.801
94	87	219,000	--	--	14	14	--	--	666	666	63.927	3.041
95	46	102,238	--	--	6	6	--	--	349	349	58.687	3.414
96	70	220,305	--	1	5	6	--	750	130	880	27.235	3.994
97	1,749	5,106,944	5	2	351	358	30,000	3,900	3,642	37,542	70.101	7.351
98	45	134,500	--	1	--	1	--	1,800	--	1,800	7.435	13.383
99	42	134,370	--	1	7	8	--	1,800	126	1,926	59.537	14.334
100	47	125,618	--	1	6	7	--	1,800	32	1,832	55.724	14.584
101	49	163,694	--	1	5	6	--	3,000	112	3,112	36.654	19.011
102	94	286,904	1	--	7	8	6,000	--	170	6,170	27.884	21.505
103	100	302,096	--	1	52	53	--	6,000	1,036	7,036	175.441	23.456
104	32	75,895	--	1	4	5	--	1,800	81	1,881	65.880	24.784
105	338	698,536	3	--	79	82	18,000	--	1,339	19,339	117.388	27.685
106	60	174,147	1	--	2	3	6,000	--	37	6,037	17.227	34.666

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm. dis.	Temp. dis.	Total	Deaths	Perm. dis.	Temp. dis.	Total		
107	53	172,338	1	--	--	1	6,000	--	--	6,000	5.803	34.815
108	55	175,004	1	1	4	6	6,000	300	38	6,338	34.285	36.216
109	72	151,787	1	--	2	3	6,000	--	74	6,074	19.765	40.017
110	50	153,693	1	1	--	2	6,000	300	--	6,300	13.013	40.991
111	76	258,026	1	1	13	15	6,000	6,000	235	12,235	58.134	47.418
112	65	128,440	1	--	11	12	6,000	--	154	6,154	93.429	47.913
113	42	114,949	1	--	4	5	6,000	--	35	6,035	43.498	52.502
114	55	83,052	--	1	3	4	--	4,500	84	4,584	48.163	55.194
115	42	100,228	1	--	--	1	6.000	--	--	6,000	9.977	59.864
116	69	153,527	2	--	9	11	12,000	--	287	12,287	71.649	80.032
117	69	186,000	2	1	12	15	12,000	6,000	348	18,348	80.645	98.645
118	32	35,506	1	1	4	6	6,000	1,800	24	7,824	168.986	220.357
Totals & Averages	9,407	25,439,066	23	20	1,057	1,100	138,000	41,250	18,163	197,413	43.241	7.760
1925 Totals and Averages	8,079	21,281,061	17	20	990	1,027	102,000	20,625	14,215	136,840	48.259	6.430

1/ As the accident reports from quarrying companies are considered confidential by the Bureau of Mines, the identity of the mines to which this table relates is not revealed.

GROUP 5.- ACCIDENT DATA FOR CERTAIN NONMETALLIC MINERAL MINES IN 1926 1/

Code No.	Average employees	Hours worked	Number of accidents				Number of days lost				Frequency rate	Severity rate
			Deaths	Perm. dis.	Temp. dis.	Total	Deaths	Perm. dis.	Temp. dis.	Total		
1	52	137,193	--	--	3	3	--	--	10	10	21.867	0.073
2	112	246,273	--	--	2	2	--	--	26	26	8.121	.106
3	51	126,561	--	--	1	1	--	--	33	33	7.901	.261
4	55	132,947	--	--	2	2	--	--	39	39	15.044	.293
5	50	140,807	--	--	7	7	--	--	51	51	49.713	.362
6	53	158,340	--	--	3	3	--	--	92	92	18.947	.581
7	109	274,744	--	--	2	2	--	--	208	208	7.280	.757
8	44	162,000	--	--	14	14	--	--	142	142	86.420	.877
9	39	121,151	--	--	8	8	--	--	109	109	66.033	.900
10	382	687,169	--	--	36	36	--	--	763	763	52.389	1.110
11	96	255,968	--	--	19	19	--	--	373	373	74.228	1.457
12	57	166,000	--	--	22	22	--	--	272	272	132.530	1.639
13	83	177,396	--	1	2	3	--	300	10	310	16.911	1.748
14	120	259,843	--	--	62	62	--	--	459	459	238.606	1.766
15	368	417,325	1	--	53	54	6,000	--	1,356	7,356	129.396	17.627
16	131	296,567	1	2	55	58	6,000	900	1,496	8,396	195.571	28.311
17	61	128,565	1	--	10	11	6,000	--	261	6,261	85.560	48.699
Totals & Averages	1,863	3,888,849	3	3	301	307	18,000	1,200	5,700	24,900	78.944	6.403
1925 Totals and Averages	1,439	3,407,064	3	4	268	275	18,000	3,150	4,913	26,063	80.715	7.650

1/ As the accident reports from mining companies are considered confidential by the Bureau of Mines, the identity of the mines to which this table relates is not revealed.

622.09
Un 32 mo
cop. 2

Serial No. 2849,
ecember, 1927.

THE LIBRARY OF THE
JUL 23 19[illegible]
UNIVERSITY OF ILLINOIS

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

ANALYSES OF CRUDE OILS FROM THE WEST TEXAS DISTRICT

By A.J. Kraemer[1], Peter Grandone[2], and C.S. Luce[2]

Introduction

The Bureau of Mines for a number of years has been studying the properties of crude petroleum from producing fields in the United States and the Western Hemisphere and has published a series of reports on these fields, including oil fields of Texas.[3]

Acknowledgments

The samples included in this report were collected during a recent field trip by H. H. Hill, Chief Petroleum Engineer of the Bureau of Mines, and H. B. Hill, Engineer in Charge of the Dallas, Tex., field office of the Bureau. The samples were analyzed under the direction of E. C. Lane at the Petroleum Experiment Station of the Bureau of Mines at Bartlesville, Okla. Production and field data were obtained from H. B. Hill of the Dallas office and Miss A. L. Clapp of the Washington office of the Bureau of Mines, and from several issues of "The Oil Weekly," Houston, Tex.

---

[1] Associate petroleum chemist, Washington, D. C., Bureau of Mines.

[2] Junior chemist, Bureau of Mines.

[3] Dean, E.W., Cooke, M.B., and Bopp, C.R., Properties of typical crude oils from the producing fields of Northern Texas, Northern Louisiana, and Arkansas; Repts. of Investigations, Bureau of Mines, Serial No. 2293, November, 1921.
Smith, N.A.C., Bauer, A.D., and LeJeune, N.F., Properties of typical crude oils from the producing fields of Southern Louisiana and Southern Texas; Repts. of Investigations, Bureau of Mines, Serial No. 2416, November, 1922.
Yant, W.P., and Fowler, H.C., Hydrogen sulphide poisoning in the Texas Panhandle, Big Lake, Texas, and McCamey, Texas, oil fields; Repts. of Investigations, Bureau of Mines, Serial No. 2776, October, 1926.
Kraemer, A.J., and Grandone, Peter, Analyses of Spindletop, Tex., crude oils; Repts. of Investigations, Bureau of Mines, Serial No. 2808, May, 1927.
Smith, N.A.C., Analyses of Panhandle and Big Lake, Texas, crude oils; Information Circ. No. 6014, Bureau of Mines, December, 1926.

Production Data

Big Lake.

The discovery well in the Big Lake field was completed during May, 1923, by the Texon Oil & Land Co., at a depth of 3,028 feet and with a daily initial production of 70 barrels. The field is owned entirely by two companies, the Texon Oil & Land Co., and the Big Lake Oil Co., and covers about 6 square miles. The average depth to the producing formation is 2,900 to 3,100 feet. The total production of the field to November 1, 1927, was approximately 22,700,000 barrels.

Chalk Field.

The discovery well in this field was completed April 23, 1926, with an initial daily production of 60 barrels. The average depth of wells producing from the Chalk sand is about 1,600 feet. This sand is about 17 feet thick. The daily production on November 15, 1927, was approximately 4,460 barrels from 106 wells.

Sample 27857 represents production from a deep well which was completed October 24, 1927 and is producing from a porous limestone at a depth of 2,956 feet.

Church & Fields Pool.

The discovery well in the Church & Fields pool was completed March 22, 1926, at a total depth of 3,030 feet, or 424 feet below sea level, with an initial daily production of 90 barrels, flowing by heads. The average depth to the producing formation is 2,900 to 3,200 feet. The natural gas from this field contains a large proportion of hydrogen sulphide and is very poisonous. The daily production of the Church & Fields Pool on November 15, 1927, was about 90,000 barrels from 150 wells; a large part was being run to storage.

McElroy Field.

The McElroy field was discovered by the Gulf Production Co. with the completion of Gulf-McElroy No. 1, Section 203, July 9, 1926. At a depth of 2,744 feet this well came in flowing by heads at the rate of 200 barrels daily. On July 23 it was deepened to 2,730 feet, and the daily production increased to 500 barrels. The average depth to the producing formation is 2,800 to 2,900 feet. The production of this field on November 15, 1927, was about 20,000 barrels daily from 54 wells, a number of the wells being restricted in production.

The Gulf Production Co. is treating part of the natural gas from this field and is removing practically all of the sulphur compounds. Although the costs for treatment are probably high, especially as considered in oil-field practice, they are believed to be warranted, because equipment is protected against corrosion. The purifying process is a regenerative one in which soda ash is used to remove the hydrogen sulphide.

McCamey Field.

The discovery well in the McCamey field was completed September 9, 1925, by Johnson and McCamey on the Baker lease. The total depth of the well was 2,272 feet and the initial daily production was 70 barrels. The average depth to the producing formation in this field is 1,800 to 2,300 feet. The production of the field on November 15, 1927, was about 18,000 barrels daily.

orld Field.

The discovery well in the World field was completed as a pumper on May 25, 1925, with an initial production of 25 barrels at a depth of 2,647 feet. The average depth of the producing formation in this field is 2,500 to 2,700 feet.

The production of the field to May 1, 1927, was 449,500 barrels. On July 1, 1927, the field production was approximately 1,400 barrels from 27 wells. On October 31, 1927, the field was producing approximately 2,500 barrels daily.

Hendricks Field, Winkler County.

The discovery well was completed November 8, 1926, by the Eastland Oil Co. and Westbrook on the Hendricks land at a depth of 3,030 feet, or 100 feet below sea level. The average depth of the producing formation is 2,700 to 3,100 feet. The largest well in the field, which was completed November 30, 1927, gauged 960 barrels the first hour. On November 15, 1927, there were 19 producing wells, 64 drilling wells, and 13 derricks up. The daily production of this field on November 15, 1927, was about 16,000 barrels.

Yates Field.

The discovery well in this field was completed October 28, 1926, by the Transcontinental Oil Co. and Mid-Kansas Oil & Gas Co. as a joint test on the Yates lease at a depth of 997 feet. The depth to the producing formation varies from less than 900 feet to more than 1,500 feet. This field is credited with being the greatest shallow field ever discovered. There were on November 15, 1927, 50 producing wells, which outline a probable proven area estimated up to 10,000 acres. A well brought in by the Transcontinental-Mid-Kansas interests on November 30, 1927, gauged 2043.9 barrels in 45 minutes.

24
24
104
52

Discussion of Results

For a discussion of the methods used by the Bureau of Mines in analyzing crude oil see Bulletin 207[4]. For a discussion of the interpretation of crude-oil analyses see Serial No. 2806[5]. Table 1 summarizes the results of these analyses by presenting some of the figures indicating physical and chemical properties of the crudes. Table 2 presents figures for the gravities of the fractions distilling at atmospheric pressure between 250° and 275° C. and the cloud points of the fractions distilling between 275° and 300° C. at 40 mm. absolute pressure. These figures indicate the "base" of a crude oil.[5]

Gravities are reported in A.P.I. degrees. This is the scale formerly known in the American Petroleum industry as "Baumé", based on the modulus 141.5 as distinguished from the Baumé scale, which is based on the modulus 140.0[6].

---

[4] Dean, E.W., and others, The analytical distillation of petroleum and its products: Bull. 207, Bureau of Mines, 82 pp. Obtainable from the Government Printing Office, Washington, D. C., at 15 cents a copy.

[5] Smith, N.A.C., The interpretation of crude-oil analyses: Repts. of Investigations, Bureau of Mines, Serial No. 2806, May, 1927.

[6] A concise statement of the reasons for the general adoption of the A.P.I. gravity scale has been prepared by the American Petroleum Institute, 250 Park Ave., New York, N. Y.

The crude oils included in this report may be divided into four groups on the basis of the characteristics of the samples.

Sample 27766, from the Big Lake field of Reagan County, is a typical high-grade intermediate-base crude similar to a great deal of the Mid-Continent production.

Samples 27856 and 27858, from the Chalk field of Howard County, represent a heavier oil that contains a larger proportion of sulphur than the Big Lake sample. However, these samples can be readily classified as intermediate-base oils.

Samples 27857, 27860, 27861, and 27862 represent crudes from a depth of 2,800 to 3,200 feet. These samples were obtained in the Chalk, Church and Fields, and McElroy fields and are heavy, high-sulphur crudes. Except for the high sulphur content, these crudes are not unlike a number of the crudes produced in Northern Texas, Northern Louisiana, Oklahoma, and Kansas. These crudes are therefore also in the intermediate class, although they approach in some respects the properties of typical naphthene base crudes.

Samples 27863, 27864, and 27867 are heavy crudes containing a comparatively small proportion of gasoline and naphtha. The first two contain more than 2 per cent of sulphur; but sample 27867, with 0.59 per cent, is a comparatively low-sulphur crude. These samples fit into the intermediate-base class, according to the Bureau of Mines method of analysis and interpretation, although they are in the heavy crude section of this class.

Sample 27859, from the Hendricks field, Winkler County, and Sample 27865, from the Yates Field, Pecos County, are classified in this report as naphthene-base crudes, although they differ considerably from typical naphthene-base crudes, such as those from Kern County, Calif.[7]

The fractions obtained in the "air distillation" of typical napthene-base crudes are of heavier gravity than fractions of the same boiling range in Samples 27859 and 27865. A typical naphthene-base crude oil does not show any kerosene distillate by the Bureau of Mines method of analysis and interpretation, whereas these samples respectively contain 5.0 and 5.6 per cent of kerosene distillate.

---

[7] Kraemer, A.J., and Smith, H.M., Properties of typical crude oils from the producing fields of California: Repts. of Investigations, Bureau of Mines, Serial No. 2595, April, 1924.

Kraemer, A.J., and Smith, H.M., Properties of California crude oils, II. Additional analyses: Repts. of Investigations, Bureau of Mines, Serial No. 2608, May, 1924.

TABLE 1

Data showing sources of samples and some of the figures indicating physical and chemical properties

Sample	Field	Sand	Depth, feet	Properties of Crude				Gasoline fraction		Viscosity at 100°F. of vacuum fractions			% Carbon residue of residuum
				°A.P.I.	%S	Viscosity at 100°F.	Pour Test, °F.	%	°A.P.I.	225-250	250-275	275-300	
27866	Big Lake	Permian lime	2900-3100	38.2	0.36	41	(a)	32.8	59.5	66	105	200	4.6
27856	Chalk	Chalk	1770-1800	32.1	.84	60	50	25.0	57.2	60	89	155	12.0
27858	do	do	1600-1630	31.3	.91	63	35	23.7	56.2	61	91	145	12.5
27857	do	Porous limestone	2956-2990	26.8	2.02	66	25	21.2	54.9	63	97	150	13.9
27860	Church & Fields	Permian lime	2900-3200	31.1	2.69	50	(a)	26.8	57.4	62	100	130	12.0
27861	McElroy	do	2800-2900	33.0	2.42	51	(a)	27.0	57.9	61	93	175	11.3
27862	do	do	2800-2900	32.8	2.40	47	(a)	26.6	57.4	65	100	180	11.2
27863	McCamey	do	1800-2300	24.5	2.29	110	(a)	14.5	50.9	70	125	230	11.7
27864	do	do	1800-2300	25.6	2.23	104	(a)	15.8	54.9	76	135	270	12.3
27867	World	do	2500-2700	29.7	0.59	80	35	18.8	54.7	69	110	200	5.8
27859	Hendricks	do	2700-3100	30.9	1.53	56	(a)	22.7	57.7	76	135	270	8.5
27865	Yates	do	1000-1500	30.0	1.61	59	(a)	22.2	56.4	73	125	270	11.6

(a) Below 5°F.

3606

TABLE 2

Data indicating the "base" of the crude oil.

Sample No.	Field	Sand	Depth	Fraction distilling at atmospheric pressure between 250°-275°C. (482°-527°F.)		Fraction distilling at 40 mm. vacuum between 275°-300°C. (527°-572°F.)	Base of Crude
				Sp. Gr.	°A.P.I.	Cloud Point °F.	
27866	Big Lake	Permian lime	2900-3100	0.835	38.0	90	Intermediate
27856	Chalk	Chalk	1770-1800	.837	37.6	90	Do
27858	do	do	1600-1630	.836	37.8	90	Do
27857	do	Porous limestone	2956-2990	.851	34.8	95	Do
27860	Church & Fields	Permian lime	2900-3200	.840	37.0	90	Do
27861	McElroy	do	2800-2900	.841	36.8	85	Do
27862	do	do	2800-2900	.841	36.8	90	Do
27863	McCamey	do	1800-2300	.858	33.4	50	Do
27864	do	do	1800-2300	.853	34.4	55	Do
27867	World	do	2500-2700	.844	36.2	80	Do
27859	Hendricks	do	2700-3100	.857	33.6	(a)	Naphthene
27865	Yates	do	1000-1500	.854	34.2	(a)	Do

(a) Below 5°F.

Sample 27066

Texas	Big Lake field	Reagan County Composite sample
Sand-Permian Lime		Depth 2,900 - 3,100 ft.
Specific gravity, 0.834		A. P. I. gravity, 38.2°
Per cent sulphur, 0.25		Per cent water, nil
Saybolt Universal viscosity at 70°F., 47 sec.		Pour point, below 5°F.
Saybolt Universal viscosity at 100°F., 41 sec.		Color, green

Distillation, Bureau of Mines Hempel Method.

Air distillation   Barometer, 746 mm.   First drop, 29°C. (84°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. Gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	2.1	2.1)					Up to 122
50 - 75	2.3	4.4)	0.668	80.3			122 - 167
75 - 100	5.5	9.9	.705	69.2			167 - 212
100 - 125	7.4	17.3	.738	60.2			212 - 257
125 - 150	6.3	23.6	.758	55.2			257 - 302
150 - 175	4.5	28.1	.779	50.1			302 - 347
175 - 200	4.7	32.8	.795	46.5			347 - 392
200 - 225	4.5	37.3	.811	43.0			392 - 437
225 - 250	5.3	42.6	.825	40.0			437 - 482
250 - 275	5.0	47.6	.835	38.0			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. Gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	5.1	5.1	.855	34.0	41	5	Up to 392
200 - 225	5.8	10.9	.861	32.8	46	50	392 - 437
225 - 250	5.1	16.0	.870	31.1	66	60	437 - 482
250 - 275	4.1	20.1	.880	29.2	105	75	482 - 527
275 - 300	6.1	26.2	.887	28.0	200	90	527 - 572

Residuum, 24.9%.   Distillation loss, 1.3%.
Carbon residue of residuum, 4.6%.   Carbon residue of crude, 1.1%.

Approximate Summary

	Per cent	Sp. Gr.	°A.P.I.	Viscosity
Light gasoline	9.9	0.689	73.9	
Total gasoline and naphtha	32.8	.741	59.5	
Kerosene distillate	9.8	.819	41.3	
Gas oil	15.7	.849	35.2	
Nonviscous lubricating distillate	6.8	.862-.864	32.7-32.3	50 - 100
Medium lubricating distillate	5.7	.864-.897	32.3-26.3	100 - 200
Viscous lubricating distillate	3.0	.897-.904	26.3-25.0	Above 200
Residuum	24.9	.940	19.0	
Distillation loss	1.3	--	--	

Sample 27855

Texas	Chalk field	Howard County Tank-battery sample
Sand-Chalk		Depth 1,770 - 1,800 ft.

Specific gravity, 0.865 — A.P.I. gravity, 32.1°

Per cent sulphur, 0.84 — Per cent water, nil

Saybolt Universal viscosity at 70°F., 92 sec. — Pour point, 50°F.

Saybolt Universal viscosity at 100°F., 60 sec. — Color, brownish black.

Distillation, Bureau of Mines Hempel Method

Air distillation — Barometer, 715 mm. — First drop, 30°C. (86°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. Gr. Cut	°A.P.I. Cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	0.8	0.8)					Up to 122
50 - 75	2.0	2.8)	0.672	79.1			122 - 167
75 - 100	3.5	6.3	.715	66.4			167 - 212
100 - 125	5.1	11.4	.743	58.9			212 - 257
125 - 150	4.8	16.2	.763	54.0			257 - 302
150 - 175	4.7	20.9	.780	49.9			302 - 347
175 - 200	4.1	25.0	.795	46.5			347 - 392
200 - 225	4.5	29.5	.810	43.2			392 - 437
225 - 250	5.0	34.5	.823	40.4			437 - 482
250 - 275	6.4	40.9	.837	37.6			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. Gr. Cut	°A.P.I. Cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	5.0	5.0	.859	33.2	41	10	Up to 392
200 - 225	6.0	11.0	.864	32.3	48	30	392 - 437
225 - 250	4.9	15.9	.878	29.7	60	55	437 - 482
250 - 275	4.8	20.7	.893	27.0	89	70	482 - 527
275 - 300	6.0	26.7	.895	26.6	155	90	527 - 572

Residuum, 31.5%. Distillation loss, 0.9%.
Carbon residue of residuum, 12.0%. Carbon residue of crude, 3.8%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	6.3	0.696	71.8	
Total gasoline and naphtha	25.0	.750	57.2	
Kerosene distillate	9.5	.817	41.7	
Gas oil	15.4	.852	34.6	
Nonviscous lubricating distillate	10.3	.867-.893	31.7-27.0	50 - 100
Medium lubricating distillate	7.4	.893-.895	27.0-26.6	100 - 200
Viscous lubricating distillate	--	--	--	Above 200
Residuum	31.5	.970	14.4	
Distillation loss	.9	--	--	

Sample 27858

Texas	Chalk field	Howard County
		Composite sample
Sand - Chalk		Depth 1,600 - 1,680 ft.

Specific gravity, 0.869	A.P.I. gravity, 31.3°
Per cent sulphur, 0.91	Per cent water, 0.7
Saybolt Universal viscosity at 70°F., 120 sec.	Pour point, 35°F.
Saybolt Universal viscosity at 100°F., 63 sec.	Color, brownish black

Distillation, Bureau of Mines Hempel Method

Air distillation   Barometer, 746 mm.   First drop, 30°C. (86°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	0.8	0.8)					Up to 122
50 - 75	2.9	3.7)	0.691	73.3			122 - 167
75 - 100	3.0	6.7	.726	63.4			167 - 212
100 - 125	3.7	10.4	.747	57.9			212 - 257
125 - 150	4.4	14.8	.764	53.7			257 - 302
150 - 175	4.3	19.1	.779	50.1			302 - 347
175 - 200	4.6	23.7	.794	46.7			347 - 392
200 - 225	4.7	28.4	.810	43.2			392 - 437
225 - 250	5.3	33.7	.824	40.2			437 - 482
250 - 275	6.6	40.3	.836	37.8			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	5.3	5.3	.862	32.7	42	15	Up to 392
200 - 225	4.6	9.9	.864	32.3	48	35	392 - 437
225 - 250	5.2	15.1	.878	29.7	61	55	437 - 482
250 - 275	4.6	19.7	.891	27.3	91	70	482 - 527
275 - 300	6.1	25.8	.893	27.0	145	90	527 - 572

Residuum, 32.1%.   Distillation loss, 1.8%.
Carbon residue of residuum, 12.5%.   Carbon residue of crude, 4.0%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	6.7	0.707	68.6	
Total gasoline and naphtha	23.7	.754	56.2	
Kerosene distillate	10.0	.817	41.7	
Gas oil	15.0	.852	34.6	
Nonviscous lubricating distillate	9.3	.866-.891	31.9-27.3	50 - 100
Medium lubricating distillate	7.5	.891-.894	27.3-26.8	100 - 200
Viscous lubricating distillate	--	--	--	Above 200
Residuum	32.1	.971	14.2	
Distillation loss	1.8	--	--	

Sample 37257

Texas | Chalk field | Howard County
Well No. 1
Depth 2,856 - 2,920 ft.

Sand - Porous Limestone

Specific gravity, 0.894 | A.P.I. gravity, 26.8°

Per cent sulphur, 2.02 | Per cent water, nil

Saybolt Universal viscosity at 70°F., 125 sec. | Pour point, 25°F.

Saybolt Universal viscosity at 100°F., 66 sec. | Color, brownish black

Distillation, Bureau of Mines Hempel Method

Air distillation | Barometer, 745 mm. | First drop, 30°C. (86°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	1.2	1.2)	0.689	73.9			Up to 122
50 - 75	1.9	3.1)					122 - 167
75 - 100	2.3	5.4	.719	65.3			167 - 212
100 - 125	4.0	9.4	.747	57.9			212 - 257
125 - 150	4.1	13.5	.772	51.8			257 - 302
150 - 175	4.0	17.5	.790	47.6			302 - 347
175 - 200	3.7	21.2	.806	44.1			347 - 392
200 - 225	4.5	25.7	.820	41.1			392 - 437
225 - 250	5.7	31.4	.836	37.8			437 - 482
250 - 275	6.5	37.9	.851	34.8			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	5.0	5.0	.878	29.7	42	15	Up to 392
200 - 225	5.8	10.8	.888	27.9	49	35	392 - 437
225 - 250	5.5	16.3	.904	25.0	63	55	437 - 482
250 - 275	5.2	21.5	.917	22.8	97	75	482 - 527
275 - 300	6.6	28.1	.929	20.8	180	95	527 - 572

Residuum, 33.9%. Distillation loss, 0.1%.
Carbon residue of residuum, 13.9%. Carbon residue of crude, 3.7%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	5.4	0.702	70.1	
Total gasoline and naphtha	21.2	.759	54.9	
Kerosene distillate	4.5	.820	41.1	
Gas oil	20.7	.859	33.2	
Nonviscous lubricating distillate	10.7	.889-.917	27.7-22.8	50 - 100
Medium lubricating distillate	7.1	.917-.932	22.8-20.3	100 - 200
Viscous lubricating distillate	1.8	.932-.936	20.3-19.7	Above 200
Residuum	33.9	1.010	--	
Distillation loss	.1	--	--	

3606

Sample 27860

Texas | Church & Fields field | Crane-Upton Counties
Composite sample
Sand - Permian lime | Depth 2,900 - 3,200 ft.

Specific gravity, 0.870 | A.P.I. gravity, 31.1°

Per cent sulphur, 2.69 | Per cent water, nil

Saybolt Universal viscosity at 70°F., 69 sec. | Pour point, below 5°F.

Saybolt Universal viscosity at 100°F., 50 sec. | Color, greenish black

Distillation, Bureau of Mines Hempel Method

Air distillation | Barometer, 746 mm. | First drop, 30°C. (86°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	1.2	1.2)					Up to 122
50 - 75	2.1	3.3)	0.681	76.3			122 - 167
75 - 100	3.6	6.9	.711	67.5			167 - 212
100 - 125	6.1	13.0	.742	59.2			212 - 257
125 - 150	6.2	19.2	.767	53.0			257 - 302
150 - 175	3.8	23.0	.782	49.5			302 - 347
175 - 200	3.8	26.8	.796	46.3			347 - 392
200 - 225	4.6	31.4	.811	43.0			392 - 437
225 - 250	5.2	36.6	.825	40.0			437 - 482
250 - 275	6.9	43.5	.840	37.0			482 - 527

Vacuum distillation at 40 mm.

Up to 200	4.6	4.6	.865	32.1	40	10	Up to 392
200 - 225	5.6	10.2	.875	30.2	47	25	392 - 437
225 - 250	6.0	16.2	.890	27.5	62	50	437 - 482
250 - 275	5.7	21.9	.903	25.2	100	70	482 - 527
275 - 300	5.8	27.7	.910	24.0	140	90	527 - 572

Residuum, 27.6%. Distillation loss, 1.2%.
Carbon residue of residuum, 12.0%. Carbon residue of crude, 3.3%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	6.9	0.697	71.5	
Total gasoline and naphtha	26.8	.749	57.4	
Kerosene distillate	9.8	.818	41.5	
Gas oil	15.6	.856	33.8	
Nonviscous lubricating distillate	10.4	.873-.903	29.7-25.2	50 - 100
Medium lubricating distillate	7.2	.903-.912	25.2-23.7	100 - 200
Viscous lubricating distillate	1.4	.912-.914	23.7-23.3	Above 200
Residuum	27.6	.972	13.6	
Distillation loss	1.2	--	--	

Sample 27801

Texas

McElroy field

Crane-Upton Counties

Sand - Permian lime

Well No. 1
Depth 2,700 - 2,900 ft.

Specific gravity, 0.860

A.P.I. gravity, 33.0°

Per cent sulphur, 2.42

Per cent water, nil

Saybolt Universal viscosity at 70°F., 59 sec.

Pour point - below 5°F.

Saybolt Universal viscosity at 100°F., 51 sec.

Color - greenish black

Distillation, Bureau of Mines Hempel Method

Air distillation

Barometer, 742 mm.

First drop, 29°C. (84°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	1.0	1.0)					Up to 122
50 - 75	2.3	3.3)	0.674	78.4			122 - 167
75 - 100	4.1	7.4	.709	68.1			167 - 212
100 - 125	5.7	13.1	.741	59.5			212 - 257
125 - 150	6.3	19.4	.766	53.2			257 - 302
150 - 175	3.8	23.2	.783	49.2			302 - 347
175 - 200	3.8	27.0	.796	46.3			347 - 392
200 - 225	4.3	31.3	.811	43.0			392 - 437
225 - 250	5.2	36.5	.825	40.0			437 - 482
250 - 275	6.7	43.2	.841	36.8			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	3.7	3.7	.865	32.1	41	15	Up to 392
200 - 225	6.2	9.9	.875	30.2	47	30	392 - 437
225 - 250	5.0	14.9	.892	27.1	61	50	437 - 482
250 - 275	5.0	19.9	.901	25.6	93	65	482 - 527
275 - 300	5.9	25.8	.908	24.3	175	85	527 - 572

Residuum, 27.4%. Distillation loss, 3.6%.
Carbon residue of residuum, 11.3%. Carbon residue of crude, 3.1%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	7.4	0.693	72.7	
Total gasoline and naphtha	27.0	.747	57.9	
Kerosene distillate	9.5	.819	41.3	
Gas oil	14.8	.857	33.6	
Nonviscous lubricating distillate	9.8	.879-.902	29.5-25.4	50 - 100
Medium lubricating distillate	7.9	.902-.911	25.4-23.8	100 - 200
Viscous lubricating distillate	--	--	--	Above 200
Residuum	27.4	.978	13.2	
Distillation loss	3.6	--	--	

3606

Sample 27862

Texas McElroy field Crane-Upton Counties

Sample from 3 wells

Sand - Permian lime Depth 2,[illegible]00 - 2,900 ft.

Specific gravity, 0.861 A.P.I. gravity, 32.8°

Per cent sulphur, 2.40 Per cent water, nil

Saybolt Universal viscosity at 70°F., 51 sec. Pour point, below 5°F.

Saybolt Universal viscosity at 100°F., 47 sec. Color, greenish black

Distillation, Bureau of Mines Hempel Method

Air distillation Barometer, 742 mm. First drop, 31°C. (88°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	1.4	1.4)					Up to 122
50 - 75	2.2	3.6)	0.682	76.0			122 - 167
75 - 100	3.7	7.3	.713	67.0			167 - 212
100 - 125	5.4	12.7	.741	59.5			212 - 257
125 - 150	6.3	19.0	.756	55.8			257 - 302
150 - 175	3.5	22.5	.781	49.7			302 - 347
175 - 200	4.1	26.6	.795	46.5			347 - 392
200 - 225	4.6	31.2	.810	43.2			392 - 437
225 - 250	5.0	36.2	.824	40.2			437 - 482
250 - 275	7.2	43.4	.841	36.8			482 - 527

Vacuum distillation at 40 mm.

Up to 200	3.5	3.5	.867	31.7	41	10	Up to 392
200 - 225	6.0	9.5	.873	30.6	48	30	392 - 437
225 - 250	6.0	15.5	.891	27.3	65	50	437 - 482
250 - 275	5.0	20.5	.902	25.4	100	70	482 - 527
275 - 300	6.7	27.2	.914	23.3	180	90	527 - 572

Residuum, 25.9%. Distillation loss, 3.5%.
Carbon residue of residuum, 11.2%. Carbon residue of crude, 2.9%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	7.3	0.698	71.2	
Total gasoline and naphtha	26.6	.749	57.4	
Kerosene distillate	9.6	.817	41.7	
Gas oil	14.5	.856	33.8	
Nonviscous lubricating distillate	10.7	.873-.902	30.6-25.4	50 - 100
Medium lubricating distillate	7.3	.902-.917	25.4-22.8	100 - 200
Viscous lubricating distillate	1.9	.917-.920	22.8-22.3	Above 200
Residuum	25.9	.981	12.7	
Distillation loss	3.5	--	--	

Sample 27863

Texas	McCamey field	Upton County
Sand - Permian lime		Composite sample Depth 1,800 - 2,300 ft.
Specific gravity, 0.907		A.P.I. gravity, 24.5°
Per cent sulphur, 2.20		Per cent water, trace
Saybolt Universal viscosity at 70°F., 225 sec.		Pour point, below 5°F.
Saybolt Universal viscosity at 100°F., 110 sec.		Color, greenish black

Distillation, Bureau of Mines Hempel Method

Air distillation   Barometer, 741 mm.   First drop, 74°C. (165°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50							Up to 122
50 - 75							122 - 167
75 - 100	1.6	1.6	0.737	60.5			167 - 212
100 - 125	1.4	3.0	.753	56.4			212 - 257
125 - 150	2.9	5.9	.757	55.4			257 - 302
150 - 175	4.5	10.4	.783	49.2			302 - 347
175 - 200	4.1	14.5	.805	44.3			347 - 392
200 - 225	5.0	19.5	.822	40.6			392 - 437
225 - 250	6.7	26.2	.841	36.8			437 - 482
250 - 275	7.3	33.5	.858	33.4			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	3.1	3.1	.882	28.9	43	Below 5	Up to 392
200 - 225	6.8	9.9	.890	27.5	54	do	392 - 437
225 - 250	7.4	17.3	.907	24.5	70	10	437 - 482
250 - 275	6.4	23.7	.919	22.5	125	30	482 - 527
275 - 300	8.8	32.5	.927	21.1	230	50	527 - 572

Residuum, 34.0%.   Distillation loss, 0.0%.
Carbon residue of residuum, 11.7%.   Carbon residue of crude, 4.0%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	1.6	0.737	60.5	
Total gasoline and naphtha	14.5	.776	50.9	
Kerosene distillate	5.0	.822	40.6	
Gas oil	18.9	.858	33.4	
Nonviscous lubricating distillate	12.5	.887-.913	28.0-23.5	50 - 100
Medium lubricating distillate	8.6	.913-.924	23.5-21.6	100 - 200
Viscous lubricating distillate	6.5	.924-.931	21.6-20.5	Above 200
Residuum	34.0	.984	12.3	
Distillation loss	.0	--	--	

3606

Sample 27864

Texas McCamey field Upton County

Composite sample

Sand - Permian lime Depth 1,800 - 2,300 ft.

Specific gravity, 0.901 A.P.I. gravity, 25.6°

Per cent sulphur, 2.23 Per cent water, 0.8

Saybolt Universal viscosity at 70°F., 200 sec. Pour point, below 5°F.

Saybolt Universal viscosity at 100°F., 104 sec. Color, greenish black

Distillation, Bureau of Mines Hempel Method

Air distillation Barometer, 746 mm. First drop, 70°C. (158°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50							Up to 122
50 - 75	0.6	0.6)					122 - 167
75 - 100	2.1	2.7)	0.696	71.8			167 - 212
100 - 125	1.9	4.6	.732	61.8			212 - 257
125 - 150	3.6	8.2	.756	55.7			257 - 302
150 - 175	3.9	12.1	.779	50.1			302 - 347
175 - 200	3.7	15.8	.799	45.6			347 - 392
200 - 225	4.0	19.8	.818	41.5			392 - 437
225 - 250	5.7	25.5	.835	38.0			437 - 482
250 - 275	6.6	32.1	.853	34.4			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	5.5	5.5	.881	29.1	43	Below 5	Up to 392
200 - 225	5.7	11.2	.891	27.3	53	do	392 - 437
225 - 250	6.8	18.0	.907	24.5	76	10	437 - 482
250 - 275	6.4	24.4	.920	22.3	135	30	482 - 527
275 - 300	9.2	33.6	.931	20.5	270	55	527 - 572

Residuum, 34.1%. Distillation loss, 0.2%.
Carbon residue of residuum, 12.3%. Carbon residue of crude, 4.2%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	2.7	0.696	71.8	
Total gasoline and naphtha	15.8	.759	54.9	
Kerosene distillate	4.0	.818	41.5	
Gas oil	19.2	.858	33.4	
Nonviscous lubricating distillate	10.4	.888-.912	27.9-23.7	50 - 100
Medium lubricating distillate	7.7	.912-.925	23.7-21.5	100 - 200
Viscous lubricating distillate	8.6	.925-.937	21.5-19.5	Above 200
Residuum	34.1	.989	11.6	
Distillation loss	.2	--	--	

Sample 27867

Texas | World field | Crockett County

Sand - Permian lime

Composite sample
Depth 2,500 - 2,700 ft.

Specific gravity, 0.878

A.P.I. gravity, 29.7°

Per cent sulphur, 0.59

Per cent water, trace

Saybolt Universal viscosity at 70°F., 150 sec.

Pour point, 35°F.

Saybolt Universal viscosity at 100°F., 80 sec.

Color, dark green

Distillation, Bureau of Mines Hempel Method

Air distillation   Barometer 746 mm.   First drop: 48°C. (118°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test °F.	Temperature °F.
Up to 50							Up to 122
50 - 75	1.5	1.5)					122 - 167
75 - 100	1.0	2.5)	0.693	72.7			167 - 212
100 - 125	3.5	6.0	.735	61.0			212 - 257
125 - 150	4.8	10.8	.759	54.9			257 - 302
150 - 175	4.3	15.1	.782	49.5			302 - 347
175 - 200	3.7	18.8	.804	44.5			347 - 392
200 - 225	4.0	22.8	.821	40.9			392 - 437
225 - 250	4.8	27.6	.835	38.0			437 - 482
250 - 275	6.8	34.4	.844	36.2			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test °F.	Temperature °F.
Up to 200	4.4	4.4	.863	32.5	42	Below 5	Up to 392
200 - 225	6.5	10.9	.868	31.5	51	25	392 - 437
225 - 250	5.5	16.4	.883	28.8	69	45	437 - 482
250 - 275	5.1	21.5	.893	27.0	110	60	482 - 527
275 - 300	6.7	28.2	.904	25.0	200	80	527 - 572

Residuum, 36.8%.   Distillation loss, 0.6%.
Carbon residue of residuum, 5.8%.   Carbon residue of crude, 2.1%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	2.5	0.693	72.7	
Total gasoline and naphtha	18.8	.760	54.7	
Kerosene distillate	4.0	.821	40.9	
Gas oil	18.9	.850	35.0	
Nonviscous lubricating distillate	10.4	.868-.890	31.5-27.5	50 - 100
Medium lubricating distillate	7.2	.890-.904	27.5-25.0	100 - 200
Viscous lubricating distillate	3.3	.904-.910	25.0-24.0	Above 200
Residuum	36.8	.949	17.6	
Distillation loss	.6	--	--	

Sample 27859

as	Hendricks field	Winkler County Pump station sample
Sand - Permian lime		Depth 2,700 - 3,100 ft.

Specific gravity, 0.876 — A.P.I. gravity, 30.0

Per cent sulphur, 1.53 — Per cent water, nil

Saybolt Universal viscosity at 70°F., 77 sec. — Pour point, below 5°F.

Saybolt Universal viscosity at 100°F., 56 sec. — Color, dark green

Distillation, Bureau of Mines Hempel Method

Air distillation — Barometer, 746 mm. — First drop, 30°C. (86°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	1.7	1.7)					Up to 122
50 - 75	1.6	3.3)					122 - 167
75 - 100	1.1	4.4)	0.679	76.9			167 - 212
100 - 125	5.3	9.7	.729	62.6			212 - 257
125 - 150	4.0	13.7	.758	55.2			257 - 302
150 - 175	4.0	17.7	.776	50.9			302 - 347
175 - 200	5.0	22.7	.797	46.0			347 - 392
200 - 225	5.6	28.3	.820	41.1			392 - 437
225 - 250	5.1	33.4	.838	37.4			437 - 482
250 - 275	6.7	40.1	.857	33.6			482 - 527

Vacuum distillation at 40 mm.

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 200	5.3	5.3	.886	28.2	43	Below 5	Up to 392
200 - 225	5.7	11.0	.897	26.3	53	do	392 - 437
225 - 250	5.7	16.7	.913	23.5	76	do	437 - 482
250 - 275	5.6	22.3	.926	21.3	135	do	482 - 527
275 - 300	6.6	28.9	.928	21.0	270	do	527 - 572

Residuum 29.7%. — Distillation loss, 1.3%.
Carbon residue of residuum, 8.5%. — Carbon residue of crude, 2.5%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	4.4	0.679	76.9	
Total gasoline and naphtha	22.7	.743	57.7	
Kerosene distillate	5.6	.820	41.1	
Gas oil	18.4	.862	32.7	
Nonviscous lubricating distillate	9.6	.894-.918	26.8-22.6	50 - 100
Medium lubricating distillate	6.2	.918-.927	22.6-21.1	100 - 200
Viscous lubricating distillate	6.5	.927-.929	21.1-20.8	Above 200
Residuum	29.7	.973	13.9	
Distillation loss	1.3	--	--	

Sample 27767

Texas	Yates field	Pecos County
Sand - Permian lime		Composite sample Depth 1,000 - 1,500 ft.
Specific gravity, 0.876		A.P.I. gravity, 30.0°
Per cent sulphur, 1.61		Per cent water, nil
Saybolt Universal viscosity at 70°F., 85 sec.		Pour point, below 5°F.
Saybolt Universal viscosity at 100°F., 59 sec.		Color, dark green

Distillation, Bureau of Mines Hempel Method

Air distillation Barometer, 757 mm. First drop, 28°C. (82°F.)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°A.P.I. cut	Viscosity at 100°F.	Cloud test, °F.	Temperature °F.
Up to 50	0.4	0.4)					Up to 122
50 - 75	1.3	1.7)					122 - 167
75 - 100	2.6	4.3)	0.688	74.2			167 - 212
100 - 125	4.9	9.2	.736	60.8			212 - 257
125 - 150	3.9	13.1	.759	54.9			257 - 302
150 - 175	4.5	17.6	.779	50.1			302 - 347
175 - 200	4.6	22.2	.799	45.6			347 - 392
200 - 225	5.0	27.2	.820	41.1			392 - 437
225 - 250	6.5	33.7	.838	37.4			437 - 482
250 - 275	6.0	39.7	.854	34.2			482 - 527
Vacuum distillation at 40 mm.							
Up to 200	4.1	4.1	.878	29.7	45	Below 5	Up to 392
200 - 225	6.0	10.1	.887	28.0	52	do	392 - 437
225 - 250	5.8	15.9	.906	24.7	73	do	437 - 482
250 - 275	5.0	20.9	.917	22.8	125	do	482 - 527
275 - 300	11.9	32.8	.928	21.0	270	do	527 - 572

Residuum, 25.7%. Distillation loss, 1.8%.
Carbon residue of residuum, 11.6%. Carbon residue of crude, 3.0%.

Approximate Summary

	Per cent	Sp. gr.	°A.P.I.	Viscosity
Light gasoline	4.3	0.688	74.2	
Total gasoline and naphtha	22.2	.753	56.4	
Kerosene distillate	5.0	.820	41.1	
Gas oil	18.5	.857	33.6	
Nonviscous lubricating distillate	9.8	.885-.912	28.4-23.7	50 - 100
Medium lubricating distillate	7.0	.912-.922	23.7-22.0	100 - 200
Viscous lubricating distillate	10.0	.922-.936	22.0-19.7	Above 200
Residuum	25.7	.984	12.3	
Distillation loss	1.8	--	--	

622.09
Un32mo
cop. 2

Serial No. 2850
December, 1927.

THE LIBRARY OF THE
JUL 23 [illegible]
UNIVERSITY OF ILLINOIS

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

STOCKS OF PETROLEUM PRODUCTS HELD BY EXPORTERS

By G. R. Hopkins

At various times in the past it has been brought to the attention of the Bureau of Mines that more and more stocks of petroleum products were being stored by exporters at or near their shipping points. It was pointed out that since these stocks are not taken into consideration in compiling the Bureau's regular monthly totals of stocks, the resultant estimates of consumption are incorrect. It was, accordingly, decided to conduct a canvass of exporters' stocks in order to determine the extent of this error.

With the assistance of the officials of the various customs districts and several outside sources, there was compiled what is considered a fairly complete list of exporters, which is appended to this report. Of the 132 companies canvassed 23 failed to reply. The 109 reports received were grouped, according to location of the stocks, in four districts, geographically as follows:

District	No. of companies canvassed	No. of replies received	No. of companies which reported holding stocks in quantities in excess of 500 barrels or 500 pounds 1/
Atlantic coast............	54	46	14
Great Lakes area, or Buffalo customs district.......	27	22	4
Gulf coast and Mexican border..................	34	28	13
Pacific coast............	17	13	2
	132	109	33

1/ Does not include those companies which regularly report their exporters' stocks as refinery stocks.

It is well known that the large exporters of petroleum and its products are also the large refining companies. The greater number of these companies, in their replies, indicated that they were accustomed to include their stocks held for export in their reports of refinery stocks regularly made to the Bureau of Mines. This was particularly true of the California refineries, which for several years have reported their total stocks on the Pacific coast. One large company reported holding stocks other than refinery stocks which were occasionally drawn on for export purposes but were used mainly for domestic trade. For this reason these stocks were not considered in this study of exporters' stocks.

Of the remaining companies 10 reported their stocks as being too small to have any effect on the situation. A total of 43 companies indicated that they either had no stocks on hand on the specified dates or merely acted as forwarding agents. In the latter case the explorer functioned as the broker, the material sold remaining in the custody of the refinery from which it was bought until it left the country. This left a total of 33 companies which reported holding exporters' stocks as shown in the following table:

TABLE I

Stocks of petroleum products held by exporters on January 1, June 30, and August 31, 1927.

(For the liquid products the quantities given are in thousands of barrels of 42 U. S. gallons. Wax and greases are reported in thousands of pounds.)

Products	Districts														
	Atlantic coast			Great Lakes area			Gulf coast			Pacific coast			United States		
	1/1/27	6/30/27	8/31/27	1/1/27	6/30/27	8/31/27	1/1/27	6/30/27	8/31/27	1/1/27	6/30/27	8/31/27	1/1/27	6/30/27	8/31/27
Crude petroleum........	- -	- -	- -	1	11	15	- -	2	- -	- -	- -	- -	1	13	15
Gasoline.....	93	181	182	- -	- -	- -	801	1,209	765	17	41	34	911	1,431	981
Kerosene.....	18	41	36	- -	- -	- -	350	259	208	2	3	3	370	303	247
Gas oil......	22	56	69	- -	- -	- -	114	147	153	- -	5	19	136	208	241
Fuel oil.....	552	458	559	- -	- -	- -	4	8	12	15	63	117	571	529	688
Lubricating oil.........	54	45	47	- -	- -	- -	96	70	65	11	24	23	164	143	139
Wax.........	167	146	887	- -	- -	- -	291	638	178	- -	- -	- -	458	784	1,065
Greases......	482	425	356	798	985	840	25	21	24	- -	- -	- -	1,305	1,431	1,220
Miscellaneous oils....	4	9	17	- -	- -	- -	34	45	29	- -	- -	- -	38	54	46

Gasoline ranked first among the products from point of volume held for export. This is to be expected in view of the fact that gasoline was also the leading refined product exported as shown in Table II. Very little crude petroleum was reported as held by exporters for the reason that by far the larger part of our exports of this commodity are consigned to Canada by pipe-line companies which include such stocks in other reports.

Considering exporters' stocks for the purpose of determining the error in the calculated figures of consumption, which was the main purpose of this study, it appears that the discrepancy was not great. For example, in the case of gasoline, exporters' stocks at their highest point, June 30, amounted to only 1,431,000 barrels, or the equivalent 3.3 per cent of the total reported by the Bureau on that date as refinery stocks, 43,768,000 barrels. The error in consumption would not be as great as this, however, since it is additions to, or subtractions from stocks that affect consumption, and not the amount held. In this case the addition to exporters' stocks during the first six months of the year was 520,000 barrels and the consumption figures were thus too high by that amount. Since the total indicated domestic demand for gasoline in the United States during that period was 136,341,000 barrels, the error was .4 per cent. The decrease in the two months, July and August, was 450,000 barrels, the consumption too low by that amount, or .8 per cent. The increase during the entire period of eight months, however, was only 70,000 barrels, a relatively insignificant amount.

Thus it would appear that over short periods of time the error introduced into gasoline consumption figures by not giving consideration to exporters' stocks is barely appreciable but that over long periods of time it is negligible. Therefore, it would not seem necessary to canvass exporters' stocks except at intervals of a year or more.

TABLE II - Exports of the major refined products classified by shipping points, 1925-1926 1/
(Thousands of barrels of 42 U. S. gallons)

Customs districts	Gasoline		Kerosene		Gas oil & Fuel oil		Lubricants		Wax (thousands of lbs.)	
	1925	1926	1925	1926	1925	1926	1925	1926	1925	1926
Atlantic coast:										
New York........	5,838	5,430	6,848	5,195	509	504	3,919	3,784	152,997	148,773
Philadelphia....	1,670	1,779	1,818	1,562	755	708	2,462	2,255	48,774	47,774
Porto Rico......)	72	123	5	2	1,415	462	207	171	13,678	14,758
Virginia........)										
Maine...........)										
Massachusetts...)										
Georgia.........)										
Rhode Island....)										
Maryland........)										
South Carolina..)										
Gulf coast:										
New Orleans.....	9,819	14,539	3,127	3,303	3,996	1,413	479	516	93,501	94,705
Sabine..........	3,242	5,355	4,222	5,343	2,948	3,056	999	765	9,399	9,508
Galveston.......	1,735	3,831	882	1,464	4,159	4,401	735	910	1,295	2,646
Mobile..........)	75	98	6	7	11	7	31	30	98	- - -
Florida.........)										
Mexican border:										
Arizona.........	64	92	1	5	207	382	6	8	151	213
San Antonio.....	58	65	1	4	14	14	37	44	3,372	1,574
El Paso.........	19	15	1	2	58	25	4	4	668	654
Northern border:										
Michigan........	1,580	1,329	14	20	136	108	45	51	262	464
Buffalo.........	158	225	57	40	127	101	104	131	612	453
Dakota..........	153	159	27	14	9	21	34	44	2	44
Vermont.........)	182	167	19	16	112	132	48	59	99	66
St. Lawrence....)										
Duluth-Superior.)										
Ohio............)										
Rochester.......)										
Pacific coast:										
Los Angeles.....	3,874	6,064	2,179	2,822	14,525	18,646	8	35	22	1
San Francisco...	1,958	3,017	1,865	2,215	3,486	4,310	465	515	2,446	4,242
Washington......)	91	192	3	2	42	226	13	21	1,803	9,509
Alaska..........)										
Oregon..........)										
Hawaii..........)										
Total....	30,638	42,480	21,075	22,016	32,509	34,516	9,596	9,343	334,179	335,584

1/ Compiled from figures of the Bureau of Foreign & Domestic Commerce.

LIST OF COMPANIES WHICH EXPORT CRUDE PETROLEUM AND ITS PRODUCTS FROM THE UNITED STATES

(Compiled during July, 1927)

Name	Address	Customs district from which exports are made
Allegheny-Seaboard Oil Corp	11 Broadway New York City	Baltimore
American Oil Co.	American Oil Bldg., Baltimore, Md.	Norfolk
American Oil Works Co.	Titusville, Pa.	Buffalo
American Trading Co.	25 Broad St., New York City	New York
Anglo-Mexican Pet. Co.	65 Broadway, New York City	Philadelphia
Anglo-Saxon Pet. Co.	801 Title Guarantee Bldg., New Orleans, La.	New Orleans
Asiatic Pet. Co.(N.Y.),Ltd.	65 Broadway New York City	Baltimore
Associated Oil Co.	79 New Montgomery St., San Francisco, Calif.	Seattle San Francisco
Atlantic Oil Producing Co.	260 So. Broad St., Philadelphia, Pa.	Port Arthur, Texas
Atlantic Rfng. Co.	260 So. Broad St., Philadelphia, Pa.	Port Arthur, Texas Baltimore Philadelphia Buffalo
Bahamas-Cuban Co.	Jacksonville, Fla.	Tampa
Geo. W. Beermaker	322 West F Street, San Diego, Calif.	Los Angeles
Belcher Asphalt & Paving Co.	1217 North Bayshore Drive, Miami, Fla.	Tampa
A. V. Berner & Co.	15-25 Whitehall St., New York City.	Philadelphia
Bassick Manufacturing Co.	Columbus, Ohio	Buffalo
Beck, Bros & Co.	Eagle Pass, Tex.	San Antonio
Bowring & Co.	17 Battery Place, New York City	Baltimore
California Pet. Co.	Security Bldg., Los Angeles, Calif.	Seattle
Camphuis & Co., Inc.	Box 214, Eagle Pass, Texas	San Antonio
The Canfield Oil Co.	Box 673, Cleveland, O.	Buffalo
Carson Pet. Co.	208 So. La Salle St., Chicago, Ill.	New Orleans

Name	Address	Customs district from which exports are made
D. W. Cass Co.	Cleveland, O.	Buffalo
Chace Export Co.	15 Whitehall St., New York City.	Boston
Chalmette Pet. Corp.	1320 Union Indemnity Bldg., New Orleans, La.	New Orleans
Cities Service Export Oil Co.	219 North Broad St., Philadelphia, Pa.	Philadelphia
Chatham Pet. Co.	29 Beaver St., New York City.	New York
Chelsea Oil & Supply Co.	17 Battery Place, New York City.	New York
Frank W. Clarke	29 Broadway, New York City.	New York
Clarkson & Ford Co.	55 Water Street, New York City.	New York
Cooper Pet. Co.	Houston, Tex.	San Antonio
Corning Oil Co.	321 Pearl Street, New York City.	New York
Crew-Levick Co.	219 North Broad Street, Philadelphia, Pa.	Buffalo
Crown Central Pet. Corp.	Box 1805, Houston, Tex.	Galveston
Robert Cruikshank Corp.	11 Broadway, New York City	New York
Damascus Mfg. Corp.	9501 Cassius Ave., Cleveland, O.	Buffalo
W. H. Daugherty & Son Rfng.Co.	Petrolia, Pa.	do
Deepwater Oil Rfng. Co., Inc.	Houston, Tex.	San Antonio
W. B. Dick & Co., Inc.	30 Church Street, New York City	New York Baltimore
S. P. Drummond	97 Water Street, New York City.	New York
Dutch Shell Line, Ross & Heyn, Agents	305 Baronne St., New Orleans, La.	New Orleans
Emery Manufacturing Co.	Bradford, Pa.	Buffalo
Enterprise Oil Co., Inc.	104 Chandler Street, Buffalo, N. Y.	do
Export Oil Co.	Spring Arcade Bldg., Los Angeles, Calif.	Los Angeles
Export Pet. Co. of Calif.	541 So. Spring St., Los Angeles, Calif.	do
Galena-Signal Oil Co.	Franklin, Pa.	Buffalo
General American Tank Storage & Terminal Co.	Union Indemnity Bldg., New Orleans, La.	New Orleans

Name	Address	Customs district from which exports are made
General Pet. Corp. of Calif.	Higgins Bldg., Los Angeles, Calif.	Seattle San Francisco
J. E. Gerrodette & Co., Inc.	17 Battery Place, New York City	New York
Gilmore Oil Co.	2423 E. 28th St., Los Angeles, Calif.	Los Angeles
Goldsmith & Co.	116 Broad Street, New York City	New York
Gorham-Durbrow	225 California St., San Francisco, Calif.	Los Angeles
Gulf Refining Co.	Frick Building Annex, Pittsburgh, Pa.	Buffalo Portland New York Norfolk Tampa Port Arthur
Gulf Rfng. Co. of La.	941 Maison Blanche Bldg., New Orleans, La.	New Orleans
Gulf States Terminal & Transport Co., Inc.	Hibernia Bldg., New Orleans, La.	do
S. Henle Inc.	8 Bridge St., New York City	New York
Higgins Bros.	Dennysville, Me.	Portland
E. F. Houghton & Co.	1047 Sixth Ave., South Seattle, Wash.	Buffalo Seattle
Hudson Oil Co.	109 Broad Street, New York City	New York Philadelphia Baltimore
Humble Oil Rfng. Co.	Houston, Texas	Galveston Port Arthur
Ironsides Company	Columbus, Ohio	Buffalo
The Island Export Co.	Keyser Bldg., Baltimore, Md.	Baltimore
Jenney Manufacturing Co.	12-18 India Street, Boston, Mass.	Boston
Kendall Rfng. Co.	Bradford, Pa.	Buffalo
Kent-Middleton Rfng. Co.	Corsicana, Texas	San Antonio
Patrick Levesque	Fort Kent, Me.	Portland
Malone Oil Co.	Cleveland, O.	Buffalo
Marland Refining Co.	Box 218, Ponca City, Okla.	Galveston
F. A. Marsily & Co., Inc.	25 Beaver Street, New York City	New York Baltimore
Metasap Chemical Co.	Harrison, N. J.	Buffalo
McColl Bros., Ltd.	Buffalo, N. Y.	do
McKean County Rfng. Co.	Bradford, Pa.	do

Name	Address	Customs district from which exports are made
Mexican Petroleum Co.	120 Broadway, New York City	Portland Tampa
Mexican Pet. Corp. of La.	Destrehan, La.	New Orleans
Moore & Munger	33 Rector Street, New York City	New York
Charles Murray	Calais, Me.	Portland
National Oil Products Co.	Harrison, N. J.	Buffalo
New England Oil Rfng. Co.	Fall River, Mass.	Boston
Newfoundland Import & Export Co.	187 Blackstone St., Boston, Mass.	Boston
New Orleans Rfng. Co., Inc.	United Fruit Bldg., New Orleans, La.	New Orleans
North American Car Corp.	607 World Bldg., Tulsa, Okla.	New Orleans
The Oster Mfg. Co.	2057 E. 61st Place, Cleveland, O.	Baltimore
Pan American Pet. Co.	10th & Flower Sts., Los Angeles, Calif.	Los Angeles
Pan Pacific Oil Co.	524 Board of Trade Bldg., Los Angeles, Calif.	do
M. W. Parsons & Plymouth Organic Lab.	New York City	Buffalo
Pennsylvania Refining Co.	Karns City, Pa.	do
The Pennzoil Co., Inc.	Oil City, Pa.	do
Peoples Wood, Coal & Coke Co.	506 Oak Street, Tampa, Fla.	Tampa
Petroleum Export Assoc., Inc.	Houston, Tex.	Galveston
Petroleum Import & Export Co.	New Orleans, La.	New Orleans
Pierce Petroleum Corp.	420 Olive St., St. Louis, Mo.	San Antonio
Pioneer Oil Rfng. Co.	San Antonio, Tex.	do
Primrose Pet. Co., Inc.	do	do
Pure Oil Co.	61 Broadway, New York City	Buffalo Baltimore Port Arthur New York
Putnam Bros., Ltd.	Houlton, Me.	Portland
Quaker Oil Products Corp.	Conshohocken, Pa.	Buffalo
Quaker State Oil Rfng. Co.	Oil City, Pa.	do
Redex Oil Co.	Warren, Pa.	do
Richard Shipping Corp.	29 Broadway, New York City	Baltimore
Richfield Oil Co.	Bartlett Bldg., Los Angeles, Calif.	Los Angeles

Name	Address	Customs district from which exports are made
Robinson-Patterson Oil Co.	29 Broadway, New York City	New York
Russell Oil Co.	San Antonio, Texas	San Antonio
A. E. Ryan & Co.	Cunard Bldg., New York City	Baltimore
H. A. Saffer	61 Broadway New York City	Philadelphia
Shell Company of Calif.	200 Bush Street, San Francisco, Calif.	Seattle Los Angeles San Francisco
Sherwood Bros., Inc.	809 Continental Bldg., Baltimore, Md.	Baltimore
Sinclair Rfng. Co.	45 Nassau Street, New York City	Philadelphia Norfolk Houston
Sinclair Rfng. Co. of La.	Meraux, La.	New Orleans
N. M. Smith	26 Broadway, New York City	Philadelphia
Smith & Nichols	121 Maiden Lane, New York City	New York
Standard Fruit & Steamship Co.	Unity Indemnity Bldg., New Orleans, La.	New Orleans
Standard Oil Co. of Calif.	225 Bush Street, San Francisco, Calif.	Seattle Los Angeles San Francisco
Standard Oil Co. of La.	Baton Rouge, La.	New Orleans
Standard Oil Co. of N. J.	26 Broadway, Room 707, New York City	Norfolk Charleston, S.C. Buffalo Baltimore
Standard Oil Co. of N. Y.	26 Broadway, Room 1122, New York City	Philadelphia New York Portland
Sun Oil Co.	Finance Building, Philadelphia, Pa.	Buffalo Philadelphia Port Arthur
Swan-Finch Oil Co.	522 Fifth Ave., New York City	Buffalo Philadelphia
The Texas Co.	Houston, Tex.	San Antonio Port Arthur New York New Orleans Portland Norfolk
Texas Mexican Oil Rfng. Co.	Laredo, Tex.	San Antonio

Name	Address	Customs district from which exports are made
Tiona Petroleum Co.	1130 Widener Bldg., Philadelphia, Pa.	Philadelphia
Trueba & Pardo	Piedras Negras Coah, Mexico	San Antonio
Union Oil Co. of Calif.	Union Oil Bldg., Los Angeles, Calif.	Seattle Los Angeles San Francisco
Union Oil Co. of Pa.	Warren, Pa.	Buffalo
Vacuum Oil Co.	61 Broadway, New York City	San Francisco Philadelphia Buffalo
Waldo, Egbert & Maltby, Inc.	Liberty Bank Bldg., Buffalo, N. Y.	do
Western Oil & Rfng. Co.	416 West 8th St., Los Angeles, Calif.	Los Angeles
West India Oil Co.	26 Broadway, New York City	San Francisco Baltimore
West Penn Oil Co.	Warren, Pa.	Buffalo
Wilshire Oil Co.	2455 E. 27th St., Los Angeles, Calif.	Los Angeles
W. E. Winship	Whitney Bldg., New Orleans, La.	New Orleans
Wolverine Lubricants Co., Inc.	Reno, Pa.	Buffalo
W. A. Wood Co.	373 Atlantic Ave., Boston, Mass.	Boston
York Oil & Chemical Co.	York, Pa.	Buffalo

622.09
Un32mo
Cop.2

Serial No. 2851,
January, 1928 .

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

THE LIBRARY OF THE
JUL 21
UNIVERSITY OF ILLI

THE WIRE SAW IN SLATE QUARRYING

SUPPLEMENTARY REPORT

By J. R. Thoenen[1]

General

Since the publication of the preliminary report on this subject in July, 1927, (The Wire Saw in Slate Quarrying, Preliminary Report, Serial No. 2820, by Oliver Bowles) the wire saw has been in constant daily operation at the quarry of the Colonial Slate Company. During this time between twenty and thirty successful cuts have been made varying in length from forty-five to ninety-two feet and in depth from six to ten feet. No accurate time records have been kept on these cuts but they have totaled over 12,000 sq. ft. of area and required 19,000 lineal feet of wire.

During these cuts the average speed of cutting has risen from the 12.8 sq. ft. per hour obtained in the original recorded tests to between 15 and 20 sq. ft. per hour, with the present rate running very close to 20 sq. ft. per hour at this quarry.

This increased cutting speed is a natural result of increasing familiarity with the characteristics and abilities of the saw and greater skill in its manipulation. Some of these cuts were in hard ribbons while others cut the ribbons transversely; thus the cuts were made under unfavorable as well as favorable conditions. The cumulative results are therefore indicative of possibly even greater efficiency in the use of this tool.

The Colonial Slate Company has purchased additional equipment and has four standards in use. Channeling machine work has been practically abandoned except for making short cuts, for example, in cutting out small sink holes in which to place wire saw standards.

The increasing success of the tests has made its influence felt in the entire district. Many operators have observed the saw in action and its accomplishment has so impressed them that two other companies have purchased and installed wire saws which are now in daily operation. Other companies have ordered saws for immediate delivery, and several companies are making definite plans to operate them in the Spring of 1928.

---

[1] Mining Engineer, Nonmetallic Minerals Experiment Station, New Brunswick, New Jersey. (In cooperation with Rutgers University).

Two Cuts with One Wire

Recently experiments have been run by the Colonial Slate Company whereby two parallel cuts a short distance apart have been made simultaneously with a single wire. Two extra standards were obtained from local manufacturers embodying improvements over the imported standards suggested by experience. Thus four standards were used and the wire strung first through one pair for one cut and then to the second pair for the second cut before returning to the drive mechanism. Each of these cuts averaged forty-five feet in length and ten feet deep equaling a single ninety foot cut. They were put down at approximately the same speed as single cuts (20 sq. ft. per hour), and caused no trouble other than that required in setting up the extra standards.

Equipment for Sinking Standard Holes.

Early Tests that Failed.

The Belgian drum drill with its forged teeth using sand as an abrasive was not successful as a means of sinking standard holes. The reasons for this were, the cumbersome nature of the tool itself, the time required to move and set it, its inability to cut holes other than vertical owing to the excessive friction set up between the long drum and the walls of the hole, and the excessive wear on the cutting teeth.

Failure of this equipment after repeated trials led to search for some other equipment more flexible and better suited to the problem. Officials of the Ingersoll-Rand Drill Company became interested and through their cooperation various schemes were tried.

An attempt was made to sink a hole by drilling a circle of small diameter holes with an air hammer drill mounted on a rotary arm. The webs between the drill holes were removed with a broaching tool thus giving a circular cut. This worked satisfactorily for shallow depths but for deep holes the binding of the tools and various other difficulties made the process so slow and unsatisfactory that it was abandoned. An attempt to drill a circle of larger holes with a shot drill was likewise unsatisfactory.

Large Diameter Shot Drill Holes.

Having determined the feasibility of cutting the slate with steel shot as an abrasive albeit the failure of the above methods it was next determined to attempt drilling holes at a single cut large enough in diameter to accommodate the saw standard and guide wheel.

For this purpose an experimental machine was constructed consisting of a simple revolving gear driven head so mounted on a fabricated steel frame as to allow inclination up to 45 degrees radially in line with the long axis of the frame. Power was supplied through a sprocket and chain drive from an eleven horse power four cylinder Continental gasoline motor mounted on one end of the frame. A hand operated clutch built integrally with the motor allowed starting without load.

The drill mechanism consists of a hollow steel shaft or drill rod splined to the revolving head with the key seat running the full length of the rod or approximately four feet. To the lower end of the drill rod is attached, by screw thread and coupling, the cutting bit or drum varying in diameter and construction with the size of the hole to be drilled. Additional drill rods with screw couplings can be inserted between the driving mechanism and the cutting drum as the depth of the hole increases.

As a preliminary experiment a twenty inch diameter bit was first attached and tried. With this equipment a hole ten feet in depth was drilled without trouble.

To allow ample room for the saw standard and 28 in. guide wheel a hole at least 36 in. in diameter was necessary. As no standard tubing of this size is available a special tube was rolled from five-eighths inch steel plate. This drum was built 30 in. long and 3 in. from the upper end was internally supported by a five-eighths inch steel circular plate or head to which the drill rod was fastened and the whole welded together.

Six two-inch slots 4 in. long cut diagonally towards the direction of rotation in the bottom edge of the bit were provided for freeing the drill shot.

With this equipment ready the drill was set up in the quarry of the Colonial Slate Company on September 10.

The hole was pitched approximately perpendicular with the plane of the split of the slate, or at 68 degrees from the horizontal. Some mechanical trouble was encountered as might be expected from such a roughly constructed experimental machine. The removal of the core itself presented a rather perplexing problem but was finally solved.

In sequence of events the operation was as follows:

The drum was revolved on the flat split of the slate using sand fed by hand as an abrasive. When the drum had cut to a depth of 2 in. it was raised and steel shot placed in the cut. The drum was then lowered and the drill started at a speed of 60 R.P.M. The drum, weighing 900 pounds itself, and drill rods provided sufficient weight for comparatively rapid drilling in this quarry.

When the drum had cut down to the limit of its internal length (when head rested on the core) drilling was stopped, the drum hoisted by chain blocks operating on a built up pipe headframe constructed on the drill frame, and set to one side.

Some broken pieces of core were removed but the major portion was found to be firmly attached to the solid slate. The core was broken loose, hoisted by the chain blocks, and removed in one piece. More shot was placed in the hole and drilling continued. This process was repeated each time the drill had cut to the depth of the barrel unless broken core stopped operations sooner. As the hole deepened much time was lost in removing water after lifting the drum preparatory to removing the core. After completing the hole, measurements showed the bottom edge of the drum to have been worn off three-eighths of an inch. About 20 lbs. of steel shot and 20 gallons of gasoline were used.

After completing the initial hole at the Colonial quarry the drill was taken to the quarry of the Chapman Slate Company and two ten-foot holes were bored. The slate here is much harder than at the Colonial and provided a much more conclusive test for the drill.

Drill Operations at Chapman's Quarry.

In starting the drill it is necessary to use sand as an abrasive owing to the physical inability of keeping shot under the cutting edge of the drum prior to the wearing of a starting ring. The first hole at Chapman's quarry started in this way was observed to cut 3 in. in the first hour. Shot being then introduced the next 18 in. was cut in 1½ hours, which illustrates the rapid increase in speed with shot.

Upon completing the first cut to the depth of the barrel, recharging the cut with shot and again starting, it was noticed that the speed of cutting was greatly reduced. The reason for this was assigned to the buoyant action of the drilling water introduced through the drill rod to the interior of the drum. At the start of this second cut the cut was not sufficiently deep to allow submergence of the drum, and the water in the interior being forced to travel under the cutting edge and out around the outside of the barrel tended to lift the barrel and counteract the weight of the drum itself. To remedy this, tripod drill weights aggregating 400 lbs. were suspended from the swivel head at the upper end of the drill rods. With this added weight the rate of cutting immediately increased to its former speed.

The results of drilling in the two quarries are given in the following table:

	Colonial Quarry		Chapman's Quarry	
	Belgian Drill Hole No. 1	I.R. Shot Drill No. 2	I.R. Shot No. 3	No. 4
Total elapsed time	45 Hrs.	29 hrs.	40 hrs.	34 hrs.
" drilling "	13 "	13 H. 44m.	19 H. 33 M.	15 "
" setting up "	25 "	2 hrs.	3 hrs.	3 "
" tearing down "	1 "	40 m.	1 hr.	3 "
" removing core time	6 "	12 H. 36 m.	16 H. 27 m.	13 "
" depth of hole	78 in.	122 in.	122 in.	124 in.
Av. " " " pr. hr.	7.48"	9.4"	6.24"	8.27"
Cost per ft.	$8.51	$3.32	$5.31	$4.49

This cost should be considerably lowered in future holes. It must be borne in mind that the machine with which this hole was drilled was only an experimental one and no provision was made for apparatus for either lifting the heavy core nor removing the water from the hole.

It is interesting to note here also that these holes 36 in. in diameter are probably as large if not the largest ever drilled by a shot drill.

The Ingersoll-Rand Drill Company are now actively engaged in developing a new type of drill for this work based on experience gained from these holes.

The Wire Saw at the Jackson-Bangor Quarry.

On September 8, the second saw in the district was placed in service at the Jackson-Bangor Slate Company quarry, at Pen Argyl, Pa. The slate in this quarry is somewhat harder than that in the Colonial although both are on the Albion Run which is classed with the so-called "soft vein" slates. In an attempt to make this initial cut particularly severe the saw was set up to cut longitudinally through the hard siliceous ribbon immediately above the "genuine" bed. This is the hardest ribbon in the quarry.

The standards were placed 125 ft. apart at each end of an open block of slate thus requiring no standard holes to be made with the shot drill. After 62 hours running time 457 sq. ft. had been cut at a cutting speed of 7.4 sq. ft. per hour. The last few hours, however, the rate had considerably decreased. Examination of the wire showed a loss of roughly one thirty-second of an inch in diameter and the outer surface of the exposed strands to be worn quite smooth. This condition was thought to account for the lower rate of cutting, in that the groove was insufficient to draw the requisite amount of sand into the cut. It was also decided that the saw had been forced too heavily at the start, which in this hard ribbon had resulted in undue wear on the wire.

An attempt to run in a new wire and ream out the first cut was tried but failed. The standards were then reset in a new position to cut parallel but about one foot below the initial cut. The saw was run in this second cut for about 19 hours when the wire again stuck and stopped. Examination showed the reason to have been the movement of the narrow beds (1 ft. from the first cut) so as to pinch the wire, and also movement of debris in an old channeler cut through which the wire ran.

The standards were again moved, a new wire strung, and a third cut started in the edge of the "genuine" bed which is the hardest of the slate beds but not as siliceous as the ribbons. This cut was 91½ ft. long and inclined at fifty two degrees from the horizontal in order to follow the natural dip of the bed.

A finer grade of sea sand containing some small amount of clay was used at the start but it was noticed that when too much water was added the mixture seemed to emulsify causing the sand to ride on top of the wire and reduce the cutting speed. Only a small amount of this sand was available and a clean silica sand manufactured from sandstone was next tried and proved quite satisfactory.

At the start five sand boxes were used and it was found rather difficult to adjust the proper amount of sand and water. During one two-hour period one of these boxes (nearest the final end of the cut) was removed and it was observed that the cutting speed increased. During the next two-hour period a second box was removed without lessening the cutting rate. This showed the possibility of conserving the quantity of sand used and also provided easier control as the spigots on the remaining three boxes could be opened wider and the volume of water better controlled.

This cut was entirely successful and when completed measured seven feet nine inches in depth and 91½ ft. long, making a total of 709 sq. ft. To this must be added 26 sq. ft. for a projection at one end of the cut or a total of 735 sq. ft. in all. The actual running time was 90 hours and the average cutting rate 8.17 sq. ft. per hour.

The standards were then reset for another cut 131 ft. long which was completed without mishap at an average rate of 9.5 sq. ft. per hour.

The Wire Saw at Chapman's Quarry

The Chapman Slate Co., at Chapman's Quarries purchased a complete wire saw outfit and started their initial cut on October 15. This cut was completed on October 19, without serious trouble. Several short stops were made as a result of mechanical trouble with the power unit, but these caused no inconvenience other than to delay the completion of the cut.

In the previously recorded cuts at both the Colonial Slate Company and the Jackson-Bangor quarries the power unit driving the saw consisted of an electric motor driving through a series of counter shafts and belts to obtain the required speed reduction. At the Chapman quarries the power was supplied by a 10 H.P., 220 volt induction motor coupled to a speed reduction unit made by the Philadelphia Gear Works.

The Chapman quarry is on the so-called "hard vein" slate which, although differing little in chemical composition from the soft vein is nevertheless considerably harder. Considerably slower cutting speed was anticipated and in consequence a short cut was tried first.

The cut as completed was 41 ft. long and 10 ft. deep and was finished in 36 hrs. running time or at an average speed of 11.4 sq. ft. per hour.

Careful measurements were made at various periods and hourly speed rates determined ranging from 5 sq. ft. per hour to 17.2 sq. ft. per hour. The variation was caused by varying rates of feeding the guide pulleys on the saw standards and the maximum rate is indicative of what may be anticipated when the operating personnel becomes better acquainted with the manipulation of the equipment.

The successful cutting of this harder slate and the comparatively higher rate of speed than was expected suggests the possibility of the utilization of the saw in much harder formations than slate and thus opens the potential field for this equipment to many other of the rock product industries.

Upward Curvature of the Saw Cut.

As mentioned in the preliminary report the upward curvature of the wire saw between the guide pulleys caused some apprehension as to its ultimate success. Continued experiments, however, have proven that this is a minor problem, cuts having been made 45 feet long with a maximum upward curve of only two inches and 90 ft. long with less than six inches. Operation of the saw after complete lowering of the guide pulleys and increased tension on the rope are the only requirements.

Sand Tests.

Screen analyses were run on four different kinds of sand used with the following results:

Screen Tests of Sands Used. (In percentages)

	1	2	3	4	5
Plus 10 m	0	0	0	0	1
Minus 10m Plus 20 m	0	6	3	0	3
" 20m " 35m	0	60	25	3	*96
" 35m	100	34	72	97	- -

* No. 35m screen used.

#1. Gray sand used at Jackson-Bangor Quarry.
2. Coarse white silica sand used at Jackson-Bangor quarry.
3. River sand from local pit " " " " "
4. Fine white silica sand " " " " "
5. Sea sand used at Colonial quarry tested December, 1926.

Samples Nos. 1, 4 and 5 gave the best service. The No. 3 sand was found to contain too many pebbles and also too much loam. The No. 2 sand was reported as too coarse with a tendency to bind the saw in the cut. Unfortunately this difficulty did not occur during the presence of the writer so he does not feel inclined to condemn this coarser material without further trial. The rate of cutting when using Nos. 1, 4, and 5 sands was affected by too many other features to determine whether one was better than another. All worked apparently equally well.

Conclusions

From the results of the tests so far with the wire saw it is evident that it will cut twice to four times as fast as a channeling machine and at correspondingly lower cost.

The saw requires one man only to operate and where a small air hoist is available not more than two men are necessary to move it from one set up to another.

There is little or no waste directly attributable to the saw cut except the actual rock cut away.

The smooth surface left by the saw on the quarry blocks can be utilized to reduce preliminary mill sawing.

The saw can be run 24 hours daily if desired without other than regular attendant labor.

The development of the core drill has adequately solved the problem left open by the failure of the Belgian drum drill and thereby made the saw available for those quarries having no other means of opening sinks for the saw standards.

Recognition of the success of the wire saw in the slate field is evidenced by the purchase of complete equipment by six operating companies and of a second complete outfit by the initial operator. In addition to this several other operators in the Pennsylvania and other fields have in contemplation the installation of saws for the spring of 1928.

Interest has been shown by the operators of other materials than slate also, and it is hoped in a future report on progress to be able to include tests on other classes of rock. -- Reports of Investigations, Bureau of Mines, Department of Commerce.

622.09
Un 32 mo
Cop. 2

Serial No. 2852.
January, 1928.

THE LIBRARY OF THE
JUL 24
UNIVERSITY OF ILLINOIS

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

CONSUMPTION OF REAGENTS USED IN FLOTATION, 1926

By Thomas Varley[1]

During the past few years, since flotation has become the paramount treatment method for most all kinds of ores, the Bureau has gathered the data on consumption of reagents used in the flotation treatment. The first report was issued in 1916.

A brief review of such reports shows the progress made in the art of flotation, and each year brings forth the development of new reagents or combinations of reagents that seem sure to survive, but research and progress spell their defeat, if not by entire elimination, at least subjects them to considerable modification.

Fortunately, close cooperation between the Bureau and the operators has been the means of an exchange of ideas in research work, and the development, in plant practice, of such research work on a commercial basis, is one of the outstanding features in milling today.

In past years flotation has been referred to generally as "oil flotation"--today it might be more properly called "chemical flotation." Minerals can be floated today without oil. Chemicals alone will do the work, showing how little was truly known about the process heretofore. The term "reagents" as used herein, includes both chemicals and oils.

The total pounds of oils and reagents consumed during the year was greater than shown in the 1925 report. The 1926 total was 201,711,795 pounds as compared with 81,666,967 pounds for 1925. The equivalent in pounds of reagent used per ton of ore for 1926 was 3.963 as compared with 1.7952 for 1925. This increase is due largely to the amount of lime which is added in the alkaline circuits, particularly in the mills treating copper ores, which accounts for the larger tonnages.

In order to counteract objectionable soluble materials present either in the ore or the mill water, modifying reagents are used to "condition the pulp" and by neutralization prevent interference of such soluble materials. Reagents of this ~~type~~ are soda ash, sodium silicate, sodium sulphite, crude soda, lime and acids. In this connection, lime is generally regarded as a "chemical," on account of its action on the minerals, and its reactions with acidic solutions or soluble salts in the ore.

---

[1] Metallurgist, Bureau of Mines, Department of Commerce.

Depressing and Accelerating Agents

The relative floatability under a standard set of conditions has been determined[2] for most sulphide minerals, also for some of the more common gangue constituents such as silica, siliceous materials free from mineral, calcite, limestone and others. Chemicals[3] seem to have a positive action on minerals -- really a different action on each, and it is this fact that is taken advantage of in differential flotation work. Different oils have a slightly different action on the flotation of different minerals and thus assist the chemicals.

The terms "sinking" or "dropping" of minerals are now common in flotation plants, which means that chemicals and oils are added to the flotation pulps to depress the undesirable floatable minerals and raise the desirable ones. For instance, galena can be floated away from sphalerite and pyrite under proper conditioning of the pulp and addition of suitable flotation reagents. In turn, certain chemicals and oils can be added which remove the depressing action of the first reagents and render the sphalerite amenable to flotation, thereby leaving the pyrite behind. Again, other reagents can be added to float the pyrite from the gangue material.

Concentration Ratios

The ratio of concentration in flotation is comparatively high because high-grade products are constantly being obtained more free from undesirable minerals and gangue than heretofore. This is shown by the reports previously published.

The summary of 1926 figures shows that the total quantity of ore reported as being treated by flotation in that year was 50,889,254 tons, from which 3,353,120 tons of concentrates were obtained, giving an average concentration ratio of 15.177 tons into 1. This ratio is slightly less than that for the 1925 figure , which was 16.301 to 1.

The data here summarized were collected by special canvass of mill operators. We believe that the summary is as complete as figures will permit. In some plants where gravity concentration is still in use, the operators reporting have had to estimate the tonnage going to flotation. Over 95 per cent of the tonnages reported are actual figures reported to the fraction of a ton, and 5 per cent are those closely estimated by operators. There are some few operators who have not reported, but their outputs are very small and would increase the total tonnage only slightly, probably not more than 1 or 2 per cent. Furthermore, the tonnages of ore treated and concentrates produced as herein recorded can not be compared with those shown in "Mineral Resources of the United States," which have been separately collected and are not classified as to process of concentration used.

---

[2] Bulletins 16 and 17, Department of Metallurgical Research, University of Utah.

[3] Head, R. E. and Tucker, E. L., Effect of cyanogen compounds on the floatability of pure minerals: Trans. Am. Inst. Min. Eng., Vol. LXXIII, pp. 354-370 (1926).

Gravity Concentration

In the general summary table for all ores as well as summaries for the different classes of ores, are shown figures for "total tonnage of ore treated," while "tonnage of concentrates treated by means other than flotation" is not shown. In many mills the ore is crushed, classified and treated by gravity concentration, some mills discard tailings without regrinding, others regrind tailings and treat by flotation.

For the reason that some of the ores milled were reported as being treated by methods other than gravity and flotation, and information relative to the several kinds of concentrates produced was lacking, it was impossible to give the concentrate tonnage figure in this report.

Summary table showing data on quantities of ore milled and consumption of reagents used in flotation, in metallurgical plants in the United States, during the calendar year 1926.

Total number of companies reporting	145
Total ore milled by concentration, flotation, and other methods, tons	66,100,527
Total ore treated by flotation, tons	50,889,254
Total concentrates produced by flotation, tons	3,353,120
Concentration ratio by flotation	15.177 to 1
Total reagents consumed (all kinds), pounds	201,711,795
Equivalent in pounds per ton ore	3.963

Reagents	Pounds
Refined hardwood creosote	1,931,897
Sodium sulphide	7,354,844
Pine oil	5,980,311
Xanthate	3,983,118
Water gas tar	26,414
Ammonia	33,288
Distillate	11,806
Coal tar	5,409
Sodium silicate	350,122
Refined coal-tar creosote	2,777,806
Cresylic acid	241,853
Lime	162,240,359
Crude oils	910,297
T & T mixture	124,048
Sulphuric acid	4,539,500
Cement	1,493,035
Copper sulphate	3,582,694
Soda ash	2,935,867
Zinc sulphate	928,394
Cyanide	658,345
N. T. U. oil	54,366

Reagents--Continued

	Pounds
Sodium carbonate	164,987
Reconstructed oils	152,085
Thiocarbanilid	111,003
Sodium sulphite	495,384
A. T.	13,589
X-Y mixture	43,130
Orthotoluidine	112,721
Miscellaneous	400,123
Total reagents consumed	201,711,795

Data on quantities of different classes of ore treated by flotation, 1926

	Total treated Tons	Treated by flotation Tons	Concentrate (flotation) Tons
Gold-silver ores	525,660	525,660	28,428
Copper ores	47,635,883	43,967,496	2,389,516
Silver-lead ores	1,040,502	607,355	44,555
Lead ores	6,226,174	1,977,576	91,345
Lead-zinc-iron ores	2,692,320	2,457,811	550,987
Zinc and lead-zinc ores	7,599,216	972,584	214,707
Lead-copper-silver	125,193	125,193	14,273
Miscellaneous	255,579	255,579	19,309
Totals	66,100,527	50,889,254	3,353,120

A complete copy of Serial No. 2852 can be obtained by addressing the Publications Section, U. S. Bureau of Mines, Washington, D. C.

622.09
Un32mo
cop.2

Serial No. 2853.

January, 1928.

THE LIBRARY OF THE
JUL 21
UNIVERSITY OF ILLI

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE - BUREAU OF MINES

THE RESISTANCE OF COAL-MINE ENTRIES TO THE FLOW OF AIR.

By H. P. Greenwald[1] and G. E. McElroy[2].

Part IV.- The Resistance Caused by Right-Angle Bends.

Introduction

This paper deals with the fourth phase of an extensive research on coal-mine ventilation factors. A comprehensive report of the entire work is in course of preparation, but abstracts of the various chapters are being prepared in order to make the major results public as rapidly as possible. Parts I, II and III were issued as Serials Nos. 2621 (July 1924), 2647 (October 1924) and 2671 (March 1925) and dealt with the resistance of unobstructed entries, the resistance due to mine cars and the resistance of timbered entries respectively.

Description of the Tests

With the last cutthrough between the two butt entries of the test section in the Experimental Mine open, the air flow was deflected around two right-angle bends in the same direction, the butt entries being 50 feet center to center and approximately 6 by 9 feet in cross section. Each bend had a dead end opening off of it; that at the first bend was in the direction of flow and that at the second bend was at right angles to the flow. For a primary test condition the inner corner of each bend was trimmed square and the dead ends were closed off with board brattices set flush with the line of the cutthrough.

The two corners of the first bend were then modified both independently and in conjunction. Various modifications of both bends in conjunction were also tested with rather surprising results as to the effect of conditions at the first bend upon the pressure losses at the second. To confirm the theory developed to fit these results a series of tests were made to give a direct comparison of the pressure losses as between two bends with the air flow deflected in the same direction at each and with the air flow deflected in opposite directions. The former is designated a "double" and the latter a "reversed" right-angle bend. This series of tests was conducted, however, on the bends at one of the intermediate cutthroughs at which the flow could be deflected in either direction at the second bend. Here also the average cross-section was 6 by 9 feet and the bends were 50 feet apart.

---

[1] - Associate Physicist, Bureau of Mines.

[2] - Mining Engineer, Bureau of Mines.

Results of Tests on a Single Right-Angle Bend

Pressure losses are expressed in terms of their ratio to velocity pressures (VP). For the average velocities of 300, 500, 700 and 900 feet per minute used in the test series, the corresponding velocity pressures are 0.0056, 0.0156, 0.0305 and 0.0505 inch water respectively. With square corners at the bend the pressure losses varied exactly as the square of the velocity but as the resistance at the bend was lowered the rate of change decreased slightly from the square relationship but not sufficiently so to become a factor of any practical importance. Results of tests at the highest velocity only are therefore given.

With the basic condition of square corners the loss due to a single bend was found to be 1.4 velocity pressures.

With the inner corner only changed to rather smooth coal surfaces, the resulting values were:

3-foot radius curve	0.75 VP
5-foot, 45 degree bevel	0.66 VP
6-foot radius curve	0.52 VP

With the outer corner only changed, the resulting values were:

Dead end open	1.38 VP
12-foot radius curve of smooth iron	1.40 VP

With curves on both corners, both with and without the addition of quarter-circle smooth vanes, the resulting values were:

3-and 12-foot radius curves only	0.60 VP
With 6-foot radius, or 1/3, vane	0.34 VP
With 7.5-foot radius, or 1/2, vane	0.34 VP
With 9-foot radius, or 2/3, vane	0.48 VP
With 6-and 9-foot radius vanes	0.33 VP
6-and 15-foot radius curves only	0.29 VP
With 9-foot radius, or 1/3, vane	0.27 VP

Results of Tests on a Double Right-Angle Bend

In conjunction with the foregoing tests on the losses at the first bend of a double bend, the losses at the second bend were also determined. It was found that the conditions at the first bend determined the relative losses occurring at the second bend and that the losses at the latter increased as the loss at the former decreased. Groups of tests were made with both high and low resistance at the second bend in conjunction with varying degrees of resistance at the first bend; and two series of tests were made with exactly similar conditions of resistance at both bends. The distance between the bends was constant at 50 feet and no tests were made to determine the effect of variations in this distance on the relative resistance of the two bends.

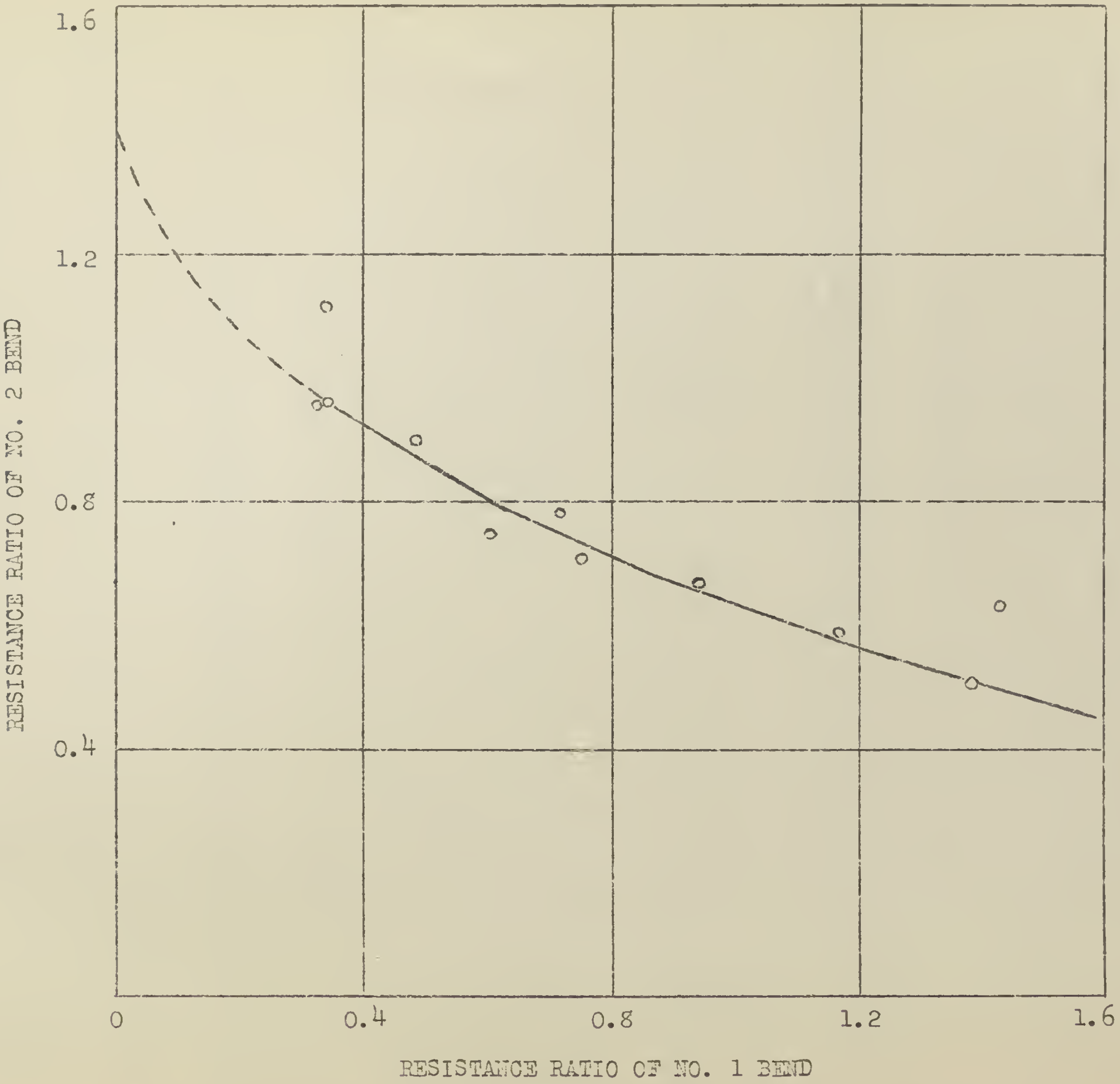


FIGURE 1.-Relation of resistance of the two bends in test section B-C.

The relative variations in resistance at the two bends for a high resistance condition at the second bend are shown approximately by the curve of Figure 1.

While the results of the tests on the first bend showed no appreciable effect of modifications of the outer corner alone on the resistance of that bend, the data on the double bend show marked reductions in pressure loss at the second bend caused by modifications of the outer corner of the first bend.

With exactly similar modifications of both bends, it was found that the absolute reduction of resistance caused by any particular modification was the same at each bend.

With square corners the resistance of the second bend was found to be 0.63 VP giving a total of 2.03 VP for the double bend on 50 foot centers as against 1.40 VP for the single bend.

Theory of Air Flow at a Double Right-Angle Bend

The pressure loss caused by bends is a measure of the power consumed in forcing the air to change its direction of motion. As the air passes around a bend that at the outer corner must travel much faster than that at the inner corner. Also, because of its inertia, the air crowds to the outside of the bend and is compressed. A rotary, as well as a translatory, motion is thus impressed while turning the corner. After the bend is passed the expansion of the compressed air gives a component of motion across the duct until all the energy stored in the rotating air is either converted to useful pressure or destroyed by friction.

If the air at a second bend is deflected in the same direction a set of operations similar to those at the first bend must ensue but they are modified by the fact that the air has cross components of motion due to expansion that will help it around the second bend and only a small amount of additional power is required.

If the first bend is modified to pass the air around it more easily less energy is required to deflect it at the first bend and therefore greater amounts of energy must be supplied at the second bend, the relative effect depending on the distance between the bends.

Results of Tests on a Reverse Right-Angle Bend

The foregoing theory will apply in full only when the air makes two successive bends in the same direction and the bends are fairly close to each other. When the second bend reverses the direction of flow, the expansion of the slightly compressed air produces a cross current which will oppose movement of the air around the second bend and thus increase the pressure loss there over that of the second bend of a double bend and in this case also the relative effect will depend on the distance between the bends.

Tests made to confirm this theory, by reversing the flow of the second of two bends 50 feet apart gave the following results:

Loss at first bend	1.33 VP
Loss at second bend of double bend	0.67 VP
Loss at second bend of reversed bend	1.12 VP
Total loss for double bend	2.00 VP
Total loss for reversed bend	2.45 VP

Conclusions

These tests show conclusively that two bends close together, a common condition in coal mine ventilation practice, should be considered as separate bends only when the flow is reversed at the second bend. For a single square cornered bend the loss may be figured as approximately 1.5 VP with an increase to 2.0 VP for a double bend of the type tested, that is, 6 by 9-foot bends on 50-foot centers. As the distance between the bends of a double bend is increased, this value would increase to twice that for a single bend. For a single bend the loss may be reduced to one-half to one-quarter the normal values by suitable modifications and for a double bend similar absolute reductions apply for either or both bends.

In the application of this data the velocity of the air flow is the governing factor. For low velocities no modifications of existing square corners would be justified. At the moderate velocities encountered in minor aircourses, cutting of the inner corner to a 45 degree bevel would be justified at semi-permanent bends. At the high velocities often encountered in main airways and especially at fan connections, a curve with a center line radius of about 1.5 diameters would usually be justified or, where the outer curve is impractical, the inner curve only. - Reports of Investigations, Department of Commerce, Bureau of Mines.

622.09
Un33mo
Cop2

Serial No. 2854
February, 1928.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF COMMERCE--BUREAU OF MINES

ADDITIONS, REMOVALS AND CHANGES IN PERMISSIBLE LIST OF EXPLOSIVES [1] FROM JULY 1, 1927 TO JANUARY 31, 1928.

By G. St.J. Perrott[2] and J. E. Tiffany.[3]

A complete list of permissible explosives tested prior to July 1, 1927 was published in Bureau of Mines Report of Investigation,[4] Serial No. 2818, "Permissible Explosives Approved Prior to June 30, 1927," by G. St.J. Perrott and S. P. Howell. The additions, removals and changes made since that date, up to and including January 15, 1928, are shown in the accompanying table.

There were no explosives withdrawn from the active list of permissibles.

---

[1] This article is not subject to copyright. Reprinting, with customary acknowledgment to the Bureau of Mines, will be welcomed.

[2] Superintendent and assistant chief explosives chemist, Pittsburgh Experiment Station.

[3] Explosives testing engineer, Pittsburgh Experiment Station.

[4] Requests for a copy of Report of Investigation, Serial No. 2818, should be addressed to the Bureau of Mines, Washington, D. C.

UNIVERSITY OF ILLINOIS-URBANA

3 0112 028089305